INNOVATIVE USE OF ON-SITE PRECAST STRUCTURES FOR LOW AND MID-RISE HOUSING

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by Quinn Dressel Jokinen, Consulting Structural Engineers
William McCreery Architects
RPA Consultants Ltd., Cost Consultants

Introduction

This project commenced by evaluating the feasibility of a large number of different on-site precast concrete construction systems for low and mid-rise housing in Alberta. Two systems, the Ucopan System and the Fulcrum Tilt System, showed particular promise and therefore were examined in detail based on the following criteria:

- economic feasibility;
- degree of sophistication of construction techniques;
- initial capital requirements;
- price variation of major cost elements;
- manpower requirements;
- flexibility of design;
- thermal and acoustic characteristics;
- appropriateness in terms of unit livability and aesthetics;
- speed of construction and susceptibility to weather conditions; and
- life cycle cost.

UCOPAN System

This system involves casting of relatively small elements on site, then hoisting these elements into place and welding the individual elements together to form an extremely rigid structure. With this system, buildings may have a modular character due to the standardization of the system. Site limitations will only marginally limit the application of the system. Structually the UCOPAN system presents no unusual engineering problems.

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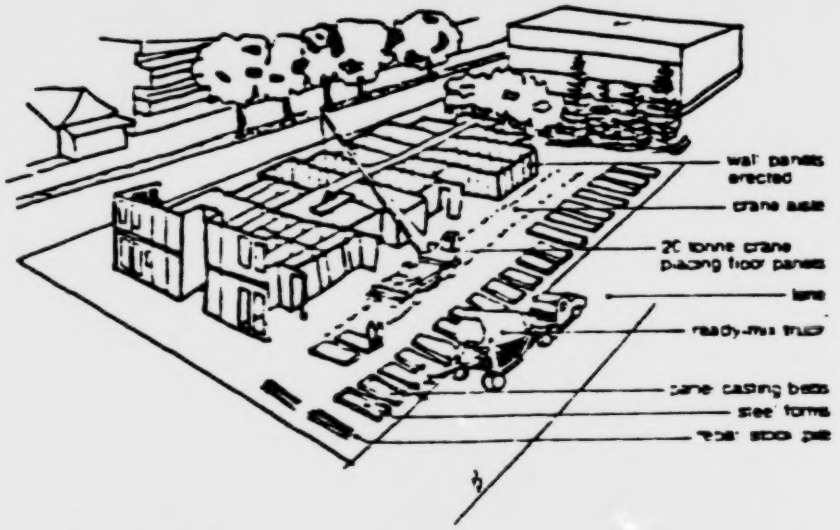

Figure 1. Ucopan System

FULCRUM-TILT System

This system involves building a cellular ("egg crate") unit horizontally on site, pouring the concrete, and then tilting the unit to a vertical position, to form the basic structural elements of a mid-rise apartment building. A precast plank is then dropped in between the "egg crate" units and stair and elevator elements. Buildings using this system do not look much different from poured-in-place structures as identical exterior finishes can be used. The structural analysis should be carried out by an engineer familiar with tilt-up systems. Sites may limit the overall height of the structures due to the space required to pour the frames. For buildings up to six storeys this should not pose much of a problem.

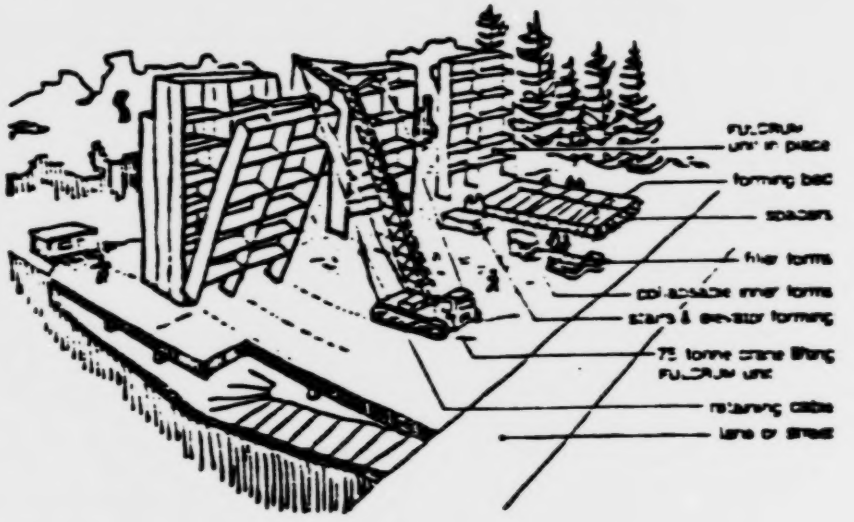

Figure 2. Fulcrum Tilt System

Conclusions

The architectural, structural and, to a lesser degree, the cost evaluations indicate that both building systems are feasible from the point of view of providing pleasant, functional living units, and can meet all accepted structural engineering standards. The construction techniques required are practical and do not require the development of any new technology.

The cost analysis of the FULCRUM TILT System indicates that there is a potential saving in the structural elements of approximately ten percent compared to cast-in-place concrete.

Cost analysis of the UCOPAN System indicates that with Alberta's current material and labour costs, the system does appear feasible compared to cast-in-place concrete, but it is more expensive than wood-frame construction. UCOPAN system costs will become feasible if lumber costs become significantly higher than concrete costs.

INNOVATIVE USE OF ON-SITE PRECAST STRUCTURES FOR LOW AND MID-RISE HOUSING

September 1983

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of the Alberta Department of Housing.

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FOREWORD

This study was made possible with funding provided by the Innovative Housing Grants Program of the Alberta Department of Housing. Originally conceived in 1978, the Program is intended to encourage, sponsor, and assist research and development in the fields of housing, site and subdivision design, energy conservation, site servicing and urban development. Generally, the aims of research funded by the Innovative Housing Grants Program are to reduce housing costs, increase the supply of appropriate housing or improve the utility or performance of dwelling units or subdivisions.

The main purpose of funding these studies is to examine the current issues in the field of housing and to develop innovations which offer improvements. Comments and suggestions regarding the information contained in these reports are welcome.

Innovative ideas come from a wide variety of applicants such as builders, developers, consulting firms, industry associations, municipal governments, educational institutions, non-profit groups and individuals. As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied.

Where possible the Department encourages the dissemination of study results under a standard cover and in a uniform format. This study,
Innovative Use of On-Site Precast Structures For Low and Mid-Rise Housing, was completed in October 1982 and subsequently released under a different cover.

Please send comments and suggestions or requests for further information to:

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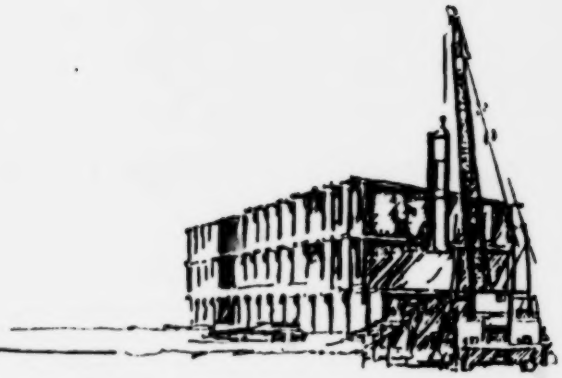
ALBERTA HOUSING & PUBLIC WORKS -- PRECAST HOUSING STUDY



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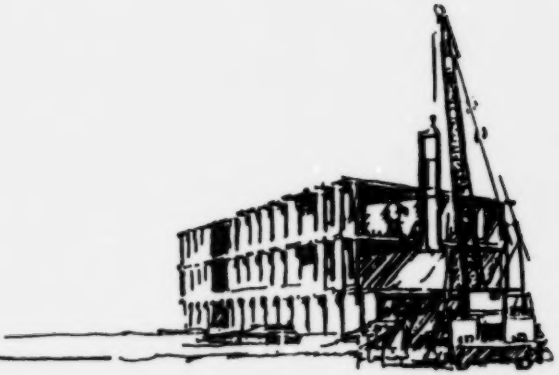

1. ACKNOWLEDGEMENTS

This report was commissioned by the Minister of Housing & Public Works, Province of Alberta, under the Innovative Housing Grants Programme, which is administered by the Planning and Research Department.

The study was funded jointly by Alberta Housing & Public Works and the Consultant firms involved in preparing the study. These firms were:

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1. ACKNOWLEDGEMENTS (CONTINUED)

We would further like to acknowledge the assistance provided by Mr. Z.A. Zielinski of UCOPAN Designers and Constructors, Montreal, inventor of the UCOPAN system, and Mr. Lucio Reale of Trojan Developers Limited, Calgary, holder of the patent for the FULCRUM-TILT system. They provided us with much of the back up information on their respective systems.

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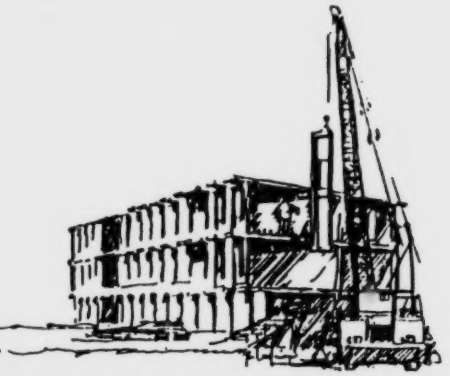


2. FORWARD

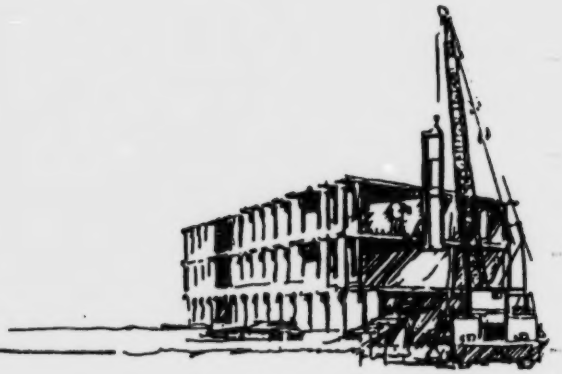
The project team of Architect, Structural Engineer, and Cost Consultant identified the need for a study on the use of on-site precast elements for residential structures, particularly in the low to mid-rise range.

It was felt that such a study was required in view of the fact that there is concern that the world supply of lumber is rapidly being depleted. This has a direct bearing in the Alberta context as a substantial quantity of lumber comes from outside the province. Also, it was felt that the most popular structural system for mid-rise construction, specifically cast-in-place reinforced concrete structures, has been developed presently to its fullest extent. The use of plant precast structures is gaining in popularity, but is subject to a wide fluctuation in pricing dependent on the current market for precast. Also, any expansion of production capacity is limited by the large capital investment required before starting up such an operation.

The use of site precast systems of relatively simple design can provide an alternate to the above systems.

A submission was made to Alberta Housing & Public Works, Planning and Research Department, and a study was commissionsed in May, 1982.

The study was carried out in three phases. The first two phases have been appended to the final report in order to display how the study evolved and to provide much of the back-up information used in the course of this project.



3. INTRODUCTION

As this report may be utilized by people unfamiliar with precast concrete techniques, as well as those involved in the construction industry, we feel that the Introduction should take the form of a brief description of precast concrete in general, and specifically the UCOPAN and FULCRUM-TILT systems.

Precast concrete systems normally involve the casting of repetitive elements in molds (forms). These elements are reinforced with steel in a manner very similar to concrete structures which are cast-in-place on a construction site. The main difference between conventional concrete structures and precast is the fact that these precast elements can be made ahead of time at locations other that the building site, and are then delivered to the site and lifted in place.

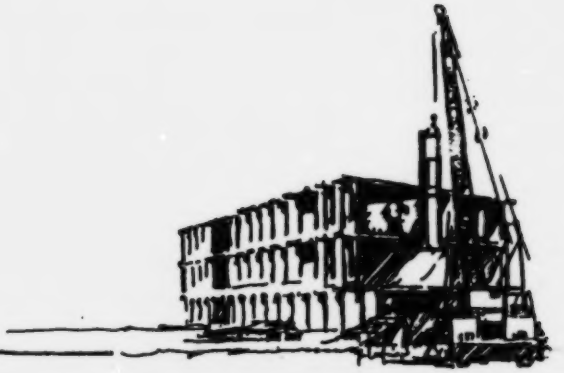
At present, most precasting in Alberta is done in large, fairly sophisticated plants which take advantage of a controlled environment to construct the elements. A large capital investment is required to establish such a plant. Transportation is also a major cost factor, as the plant itself has to be centralized, usually in one of our two urban centres, whereas the actual site of construction can be any location in the province.

Site precasting involves setting up a plant on a temporary basis, on, or adjacent to the actual building site. This has the advantage of eliminating transportation costs & handling damage, and the casting methods, forms and so on can be tailored to the specific project. Relatively little capital investment is required other than a few standardized forms. The difficulty with site precasting is that the Contractor requires a certain level of sophistication in his supervisory staff to ensure quality control.

The UCOPAN system involves casting relatively small elements on the site, and then hoisting these elements into place to form a "house of cards" which are then connected together by welded elements to form an extremely rigid structure.

The FULCRUM-TILT involves building a cellular ("egg crate") unit horizontally, and then tilting up these units to a vertical position, to form the basic structural elements of a mid-rise apartment building. A precast plank, which can either be site-cast or plant-cast, is then dropped in between the "egg crate" units and the stair and elevator elements.

A perspective of a typical UCOPAN building site, and a typical FULCRUM-TILT project are included in Section 6 of this report to further illustrate these systems and the construction procedures involved.



4. STUDY PROCEDURES & METHODOLOGY

The objective of our study is to evaluate the feasibility of the use of on-site precast techniques for low and mid-rise housing in Alberta.

We have evaluated two existing systems, the FULCRUM TILT System and the UCOPAN System. We did not, however, limit ourselves just to these systems. We carried out literature research to determine what other systems were available.

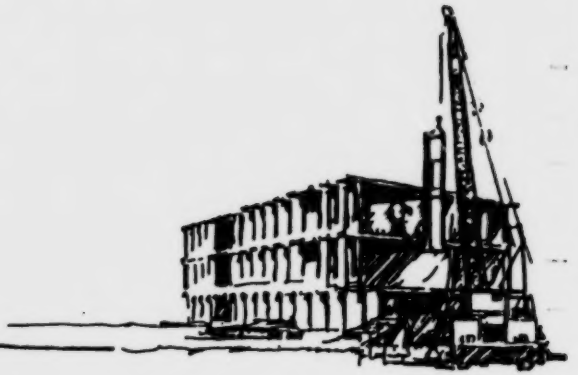
The following factors were evaluated for each of the systems under consideration:

1) Economic feasibility
2) Degree of sophistication of construction techniques
3) Initial capital requirements
4) Price variations of major cost elements
5) Manpower requirements
6) Flexibility of design
7) Thermal and acoustic characteristics
8) Appropriateness of system in terms of unit liveability and built-form aesthetics
9) Speed of construction, including lead time and susceptibility to weather conditions
10) Life-cycle cost

4. STUDY PROCEDURES & METHODOLOGY (CONTINUED)

Our work has been undertaken in the following phases:

Phase	Task	Method
1	Literature Search	Computer library search Literature on existing systems has already been compiled by Quinn, Dressel, Jokinen and William McCreery Architects Ltd.
2	Selection of final (2 or 3) systems to be evaluated.	Evaluation by Architect, Engineer, and Cost Consultants.
3	Development of selected systems	Architect and Engineer prepare comparitive sketch design for a prototypical 20 unit cluster for each system.
4	Evaluation of schemes	Architect, Engineer and Cost Consultant compare the schemes and evaluate the systems.
5	Prepare of final report and dissemination	Architect and Engineer prepare drawings, written reports, photographs, models.



A. ARCHITECTURAL

A.1 DESIGN

A.1.1. SITE PLANNING FLEXIBILITY

UCOPAN - Because of the modular "grid", based on the 1300 mm spacing, the site planning on a UCOPAN scheme is quite flexible. Various shapes are possible in plan: L-shapes, U-shapes, rectangular, possibly even 45° angled plans. On tight sites, the UCOPAN system does not lend itself to exact permissable side yards because of the modularity. Although it requires some casting and storage area, usually the rear yard portion of the site, this constraint is not as severe as with the FULCRUM-TILT System.

Sloping sites are not too difficult to handle with UCOPAN. The building can be stepped along any of the modular lines by partial panels created from an adjustable form. A large flat area is not needed for casting very large components. On the other hand, the movement of cranes, casting equipment, concrete trucks, etc., would make the system more complex than stick frame building on a severe slope.

The UCOPAN system is adaptable to remote sites, as well as urban sites, providing an adequate source of concrete is available, either ready-mix or site-batched.

Parking below the building can be provided with a slab-band concrete deck similar to stick built. The system is easily utilized in remote sites due to the minimal heavy equipment and small components.

FULCRUM-TILT - Site planning is a critical step in the FULCRUM-TILT system. Not only does the finished building have to logically be located by conventional criteria, it also has to allow for casting and tilting operations during construction. Normally, the rear yard or parking deck can serve this purpose. In our example, the 130' (39.6 m) lot depth effectively limits the building height to 6 storeys. With a little juggling, the width of tilt-up units and infill sections can usually be adjusted to take full advantage of minimum side yards.

Hilly topography where stepped foundations are necessary present problems for this system. A large, flat casting area is needed and heavy cranes must be able to move about easily. A conventional poured-in-place apartment building would be better for steep sites.

Underground parking is easily handled in a conventional cast-in-place garage level beneath the FULCRUM-TILT portion. Care must be taken in the design, however, to align the FULCRUM-TILT bearing points over the beams in the parking structure below.

A.1.2. Flexibility of Unit Layouts, Modelling, etc.

UCOPAN - Here, UCOPAN requires fixed, repetitive modular spacing to make the system work. Non-bearing walls can be located virtually anywhere, but bearing walls, the cross walls in our schemes (see sketch page 50) must be located exactly on regular modular spacings. This is not different from many conventional concrete or precast concrete and masonry bearing wall systems, but is in contrast to stick building.

Offsets in the building face must, in general, fall along the modular spacings as well, although we experimented in the Senior's scheme with a tub-shaped "greenhouse" panel to provide exterior modelling. Substantial cantilevers are a problem, requiring the balconies either to be fully recessed, or as in our scheme, supported on UCOPAN frames or posts.

Being strictly "true to the system" would result in a boring, simple, flat roof everywhere. For visual relief, both our schemes employ sections of sloped roofing. This can be easily achieved by blocking out standard panels at the appropriate roof slope to form gable infill units (see UCOPAN parts Kit, page 55).

By arranging the panels to bear from cross-wall to cross-wall, the main elevations (see sketch page 49) become non-bearing allowing them to be infilled conventionally. This allows for considerable variety in elevation treatments as well. In the end, there must be a trade-off between rigidly respecting the simplicity of the system, and creating more variety and panel types and conditions.

FULCTUM-TILT - As with conventional concrete apartment structures, FULCRUM-TILT unit layouts are largely governed by: a) underground parking garage column spacings, and b) reasonable spans from cross wall to cross wall. There is some flexibility here, however, since the system is not "modular" in its' dimensions. Naturally, though, the FULCRUM TILT sections should all be identical to allow repetitive use of the forms.

Aesthetic modelling and massing are relatively easy to accomplish. The building can be terraced or stepped back by simply casting some 4 or 5 storey sections. Balconies can be cantilevered, at least partially. Since the front and rear elevations are completely non- bearing walls, there is no restriction here in materials, window openings, cut-outs or projections.

General

Innovative development of these construction systems as they interface with sub-systems such as interior and exterior finishes, cladding, mechanical, electrical systems, etc., will yield additional cost savings.

A.1.3. FLEXIBILITY OF OPENINGS

UCOPAN - Stairwells in the UCOPAN system require that the wall be an even number of panel sizes; in our case, two full panels. Window and door openings in bearing walls must coincide with the centre of a panel. Plumbing and electrical risers can be fed through the recessed areas of the panels themselves in many cases. Large vertical service shafts require cored-out holes, or special floor panel openings.

FULCRUM-TILT - Stairwells and elevator shafts can be separate FULCRUM-TILT elements. In our scheme, the rear of the elevator core doubles as an enclosure for one of the stair shafts. Stair flights themselves are most logically site precast concrete. Vertical service shafts, risers and stacks require blocking out of floor openings when casting the FULCRUM-TILT sections. This is a reasonably simple operation.

A.1.4 FINISHED APPEARANCE AND MAINTENANCE

UCOPAN - While not a factory produced product in the true sense, UCOPAN panels can be site-cast to close tolerances and consistently high-quality finishes. As well, many of the textures and treatments available to "architectural precast" can be applied to UCOPAN, such as form liners, exposed aggregate, sandblasting, etc. Potentially, even the interior cross walls can be finished in this manner. Because of the relatively small panel size, imperfectly cast panels can be spotted before installation, and rejected. This is not possible with FULCRUM-TILT.

The many exterior wall joints in a UCOPAN system are one of its most severe drawbacks. Aside from air infiltration and leakage (see Thermal and Moisture Protection) these joints present some potential for misalignment and are labour intensive. The exposed exterior concrete finish is maintenance free and interior surfaces require minimal finish (eg. acoustic spray for ceilings and smooth concrete filler for walls). A shallow topping or feathering is required on the floors.

FULCRUM-TILT - Concrete poured vertically into wall forms, though in this case only 1200 mm high, runs the risk of separation, and honeycombing can only be detected after the forms are stripped. The tolerances of the FULCRUM-TILT sections and the finished appearance can be closely controlled using steel forms.

Micro-adjusting and leveling can be accomplished by jacks after the section is tilted into place, nevertheless, floors require a topping or feathering. Exterior walls normally require strapping, insulation and drywall as in conventional construction methods.

A.1.5 USER ACCEPTANCE

UCOPAN - Any housing is appreciated by the public if it delivers an acceptable product at an affordable price. Functional plans and varied interiors and exteriors with the UCOPAN system are comparable if not superior, to traditional methods for housing construction.

FULCRUM-TILT - The average user of a FULCRUM-TILT building will perceive little difference between it and a comparable "normal" apartment building.

A.1.6 FREEDOM FROM HEIGHT LIMITATIONS

UCOPAN - The UCOPAN system was selected for in-depth study because it did not require a high degree of sophistication in the Contractor. Consequently, it would best be used by "home builders" for structures in the 3 to 4 storey range. In theory, this system could be built to the 20 storey range, but the small panel size and resultant large number of pieces would render it uneconomical.

The UCOPAN H-Frame Module or Maxi-Panel systems would be more suitable for mid and hi-rise construction.

As well as the conventional 3½ storey walk-up, the Midi Panel system would also lend itself well to stacked 2 storey townhouses. It could also be adapted to multiple levels of stepped terrace housing on sloped sites.

FULCRUM-TILT - The practical limit of FULCRUM-TILT is about six storeys. Higher than this, the system becomes unweildy, requiring excessively large casting areas and very high capacity cranes. Anything from single storey up to 6 storeys appears to be practical, with the greatest savings in the mid-rise 4 to 6 storey range.

A.1.7 FUTURE FLEXIBILITY AND ADAPTABILITY

UCOPAN - Future additions to a Ucopan building presents the usual problems of making structural floor connections to the existing building, but these can be overcome in fairly conventional ways. As with any bearing wall panel system as opposed to a column system, the location of the bearing cross walls must remain fixed in future renovations. However, normally this type of housing is not renovated substantially.

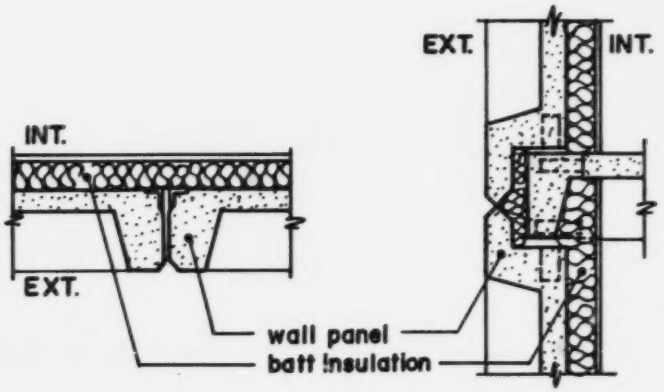
FULCRUM-TILT - As with UCOPAN this system is not better or worse than average. As well, most buildings today are built to the allowable limit for a given site, permitting only minimal future alteration.

A.2 THERMAL

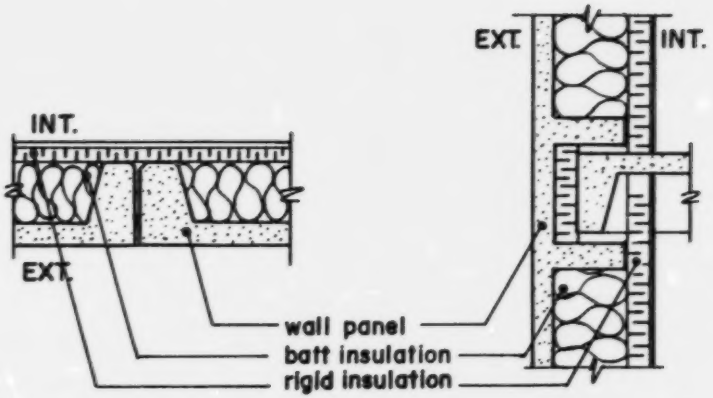
A.2.1 EASE OF INSULATION

UCOPAN - The "pan" recess in the UCOPAN panels gives additional space for insulation, an advantage over conventional poured, masonry or stud walls. In addition the spacing of the panel ribs permit direct application of interior finishes (eg: drywall, etc), eliminating the need for extensive furring.

Non-structural exterior walls in the UCOPAN system can consist of UCOPAN panels as aesthetics and costs suggest, but in all likelihood an infill stud or panel solution will provide a superior solution. In addition, a higher insulation value can be obtained, and it is easier to eliminate cold bridge problems.



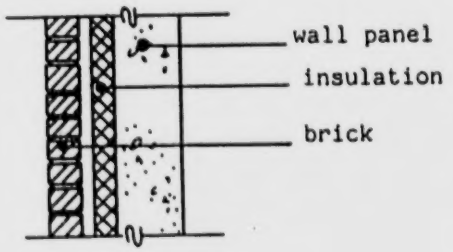
ALTERNATE - 1



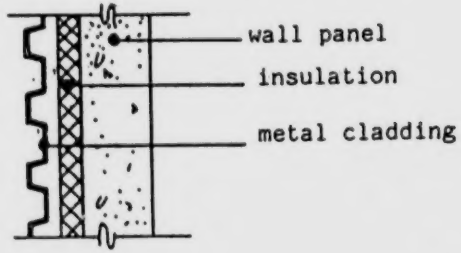
ALTERNATE - 2

FULCRUM-TILT - In the FULCRUM-TILT system face walls are infilled with stud or panel elements, and as previously mentioned for the UCOPAN, a variety of exterior finishes can be achieved, as well as the necessary level of insulation, and elimination of cold bridges.

FULCRUM-TILT - Insulation problems here are mainly restricted to the end walls. A separate insulating-type cladding is the best solution, since the concrete otherwise needs to be finished in any case on the exposed exterior surface.



FACE BRICK



METAL CLAD

Other cladding materials such as architectural precast, stucco, etc. can also be used as exterior cladding in end wall conditions.

A.2.2 RESISTANCE TO AIR INFILTRATION

UCOPAN - Unless care is taken in installation, any poly-vapour barrier is only as good as the installer. In particular, joints must be lapped and caulked, openings for electrical boxes gasketted, etc. In practice, this is rarely done carefully enough, but is especially important in a UCOPAN building where the panels are caulked against rain penetration and air movement within the exterior skin is restricted.

FULCRUM-TILT - The end walls are inherently good, provided the joints are well caulked. The front and rear walls are of conventional construction.

A.2.3 THERMAL MASS

UCOPAN - Certainly UCOPAN has a greater thermal mass than comparable wood frame buildings. There is a potential, if realized in unit layout, for utilizing the thermal storage capabilities of the floor and wall panels.

FULCRUM-TILT - FULCRUM-TILT's thermal mass is comparable to conventional concrete apartment buildings with perhaps more mass in the "cross-wall" elements of the system which again, together with the floors, can be used as thermal storage.

A.2.4 COLD BRIDGES

UCOPAN - Careful detailing is necessary to at least minimally isolate the exterior concrete elements from the interior heated spaces. The edges of the panels, which effectively form ridges which project inwards, or outwards, and the connection of floor panel and wall panels must be thermally broken. (See sketches Page 56). On the other hand, UCOPAN allows the balconies to be easily thermally isolated from the heated interior spaces by allowing an air gap between the balcony slab and the interior slab.

FULCRUM-TILT - Cold bridges in the FULCRUM-TILT's system occur in the balcony slab, and balcony wing walls. This occurs in the FULCRUM-TILT and drop-in sections. This is no different from conventional cast-in-place concrete construction.

A.3 ACOUSTICS

Ease of Attaining Sound Transmission Coefficient

UCOPAN - Tests have to be performed. The UCOPAN party walls require caulking, and sound blankets or boards in specific areas. Floor impact noises can be attenuated within the structure by utilizing established methods such as acoustic topping, cushion flooring, and acoustic spray to control sound transmission within acceptable limits.

FULCRUM-TILT - This system is excellent with sealed joints. It inherently has the mass and internal monolithic horizontal-to-vertical joints. Impact noise is controlled as above.

A.4. MOISTURE PROTECTION

Exterior Sealing

UCOPAN - With appropriate care in caulking a tight building can be achieved, thereby realizing future energy savings. The roof membrane of the UCOPAN building can be any one of a variety of conventional flat roofs, built-up, inverted, single-ply membrane, etc., applied to a sloped topping on the top side of the panel. Waterproof concrete could be utilized in roof panels thereby providing an integral water seal, thus eliminating the roofing trade, particularly desireable in remote locations. The thermal insulation would be applied to the underside of the structure. This has been successfully utilized in other systems.

FULCRUM-TILT - FULCRUM-TILT presents no unusual sealing problems.

A.5 MECHANICAL/ELECTRICAL

A.5.1 HVAC, WIRING, PLUMBING

UCOPAN - As mentioned previously under "Flexibility of Openings", servicing in a UCOPAN building is largely incorporated within the wall recesses. Forced warm air, electric, and hot water heating systems can be accomodated in this system. As well, standardized horizontal raceways are incorporated in the panels.

FULCRUM-TILT - Refer to the text on "Flexibility of Openings" for general comments. Wiring is difficult to incorporate within the poured walls, but can economically be incorporated in a baseboard-type strip and chase. Heating is restricted to electric baseboard or hot water systems.

A.5.2 Future Maintenance/Flexibility

UCOPAN - Access to mechanical/electrical services is relatively easy in a UCOPAN building, generally being covered by drywall on at least one side.

FULCRUM-TILT - Problems of maintenance and modifications to services in a FULCRUM-TILT apartment are similar to or better than a conventional concrete apartment building, and there is no danger of severing a prestressing tendon, for example, when coring floor slabs for relocated services.

GENERAL - In both cases the service openings are usually blocked out, and their locations are standardized. As a result services in walls can be more easily located than in the less controlled stick built or poured in place construction.

A.6 FIRE PROTECTION/CODE CONFORMANCE

UCOPAN - To obtain party wall joints, they must be in-filled with an approved firestopping such as "Fire Barrier" in order to obtain the required separation.

The UCOPAN floors, if not finished with a topping, require grouting or caulking of the joints to attain the required rating, 3/4 hour in 3 storey buildings, and 1 hour in 4, 5 and 6 storey buildings.

FULCRUM-TILT - The floor joints require grouting or topping, and the party wall joints require firestopping by in-filling, as above.

5. SYSTEMS EVALUATION (CONTINUED)

S.1 STRUCTURAL DESIGN

S.1.1 TECHNOLOGY:

UCOPAN has been widely used in the Third World. Two projects have been successfully completed in Alberta and the system is similar in concept to plant produced precast systems used extensively throughout Alberta.

FULCRUM-TILT will require considerable design development before the first project can be implemented. However, no new materials or technology are required as the concept has certain elements in common with the popular Tilt-Up systems used for industrial warehouse construction in Alberta.

S.1.2 DESIGN:

UCOPAN - After the initial design of standardized panels, very little engineering is required for conventional projects. Load tables can be easily developed for a wide variety of panel sizes and building configurations. Unusual panel sizes, structural configuaration and change in material strengths, can be handled by any compentent Structural Engineer using basic engineering principles.

FULCRUM-TILT - The design of elements of this system would most probably have to be carried out on a project-by-project basis. The most serious design consideration is erection stresses as the units are tilted. This normally is carried out by an engineering office having extensive knowledge of the system. This is the case, not because sophisticated analyses are required, but rather because the practical considerations of building such a project can only be gained, and refined through exposure to a number of FULCRUM-TILT projects.

S.2 MATERIALS

S.2.1. CONCRETE:

The concrete mix utilized in both the FULCRUM-TILT and UCOPAN systems is readily available from ready-mix supplier in all medium sized communities in Alberta. We briefly considered the use of semi-lightweight and light-weight concrete for both schemes. Considerable benefits will be derived in the erection process, particularly in allowing the use of light hoisting equipment with the lighter components.

However, semi-lightweight concrete is only available in Calgary on a regular basis, and has a significant cost premium. We are not aware of any supplier of lightweight concrete operating in the province. The introduction of such a product would involve new technology and hence, we decided to eliminate it so as not to introduce too many new features on systems which would be undertaken by relatively unsophisticated Contractors.

S.2.2. REINFORCEMENT:

The use of post-tensioned or pre-stressed reinforcement was considered and rejected for much the same reason as the lightweight concrete. If a Contractor actually proceeded to the point of implementing a project, a detailed analysis will be appropriate at that time. The most serious implication of using the pre-stressing will be the need to reinforce the formwork to take the jacking forces. This will only be economical if a large volume of units were guaranteed. The use of post-tensioning requires a high level of technical competence on the Contractor's part.

S.2.3. FORMWORK:

It is envisioned that steel forms are fabricated to accommodate a fixed module in each system. Ideally, these forms are made available to smaller Contractors on a monthly rental basis. The Cost Analysis, provided in this report, is based on this premise. With proper maintenance, a well designed and constructed set of forms will have a useful life of up to ten years.

The UCOPAN system also lends itself to a concrete mold forming system. This involves building one "positive" pattern of the UCOPAN elements in steel. These are transported from site to site and serve as molds for "negative" concrete models which in turn, serve as disposable forms for the finished building elements. This concept is particularly attractive for remote locations.

The FULCRUM-TILT system can be formed using conventional wood/plywood forms. However, the useful life of such forms is limited. Also, dimensional tolerances and surface finishes are more difficult to maintain.

S.3 CONSTRUCTION PROCEDURES

S.3.1. GENERAL:

UCOPAN construction consists of casting in steel forms a series of reinforced concrete panels. In order to limit the number of forms required for each type of element, the

maximum number of pour cycles must be used. This means that the first thing to be done on moving on site, is to set up the casting area and start stockpiling elements. This in turn, requires that sufficient site area be left to stockpile and cast the units at the same time as excavation and foundations are proceeding. The erection of UCOPAN elements is carried out in a fashion similar to the erection of conventional plant precast pieces.

FULCRUM-TILT vertical elements are cast in a horizontal form in full height units. Reinforcement and inserts are fairly conventional. However, the relatively large size and weight of these units, together with the need to level and adjust them once they have been tilted-up, requires that the Project Superintendant have above average technical background and experience. The casting area is assumed to be a concrete slab over underground parking, a condition which is typical in any case on an urban site. The weight of FULCRUM-TILT casting and construction equipment can be supported either by shoring temporarily the parking deck, or by providing additional capacity in the design of this slab, a normal procedure.

S.3.2. LABOUR SKILLS:

As stated previously, the development of these systems for the sample projects was predicated on using labour skills normally available to General Contractors currently involved in this scale of project. The highest trade skill is a welder for each site. As stated in S.3.1. above, the superintendant for a FULCRUM-TILT project also requires a higher level of training and experience.

S.3.3. SPECIALTY HARDWARE:

UCOPAN element inserts are very standardized and can be readily obtained from local suppliers.

FULCRUM-TILT inserts for lifting will probably have to be custom designed, but can be manufactured locally. Also, a lifting beam system would be required. The beam system could be rented with the forms or obtained from the mobile crane supplier.

HOISTING:

Cranes required for both UCOPAN and FULCRUM-TILT are readily available in Alberta on a rental basis.

5. SYSTEMS EVALUATION (CONTINUED)

L.C.C. LIFE CYCLE COSTING & COST ANALYSIS

L.C.C.1. MATERIALS: WOOD vs. CONCRETE

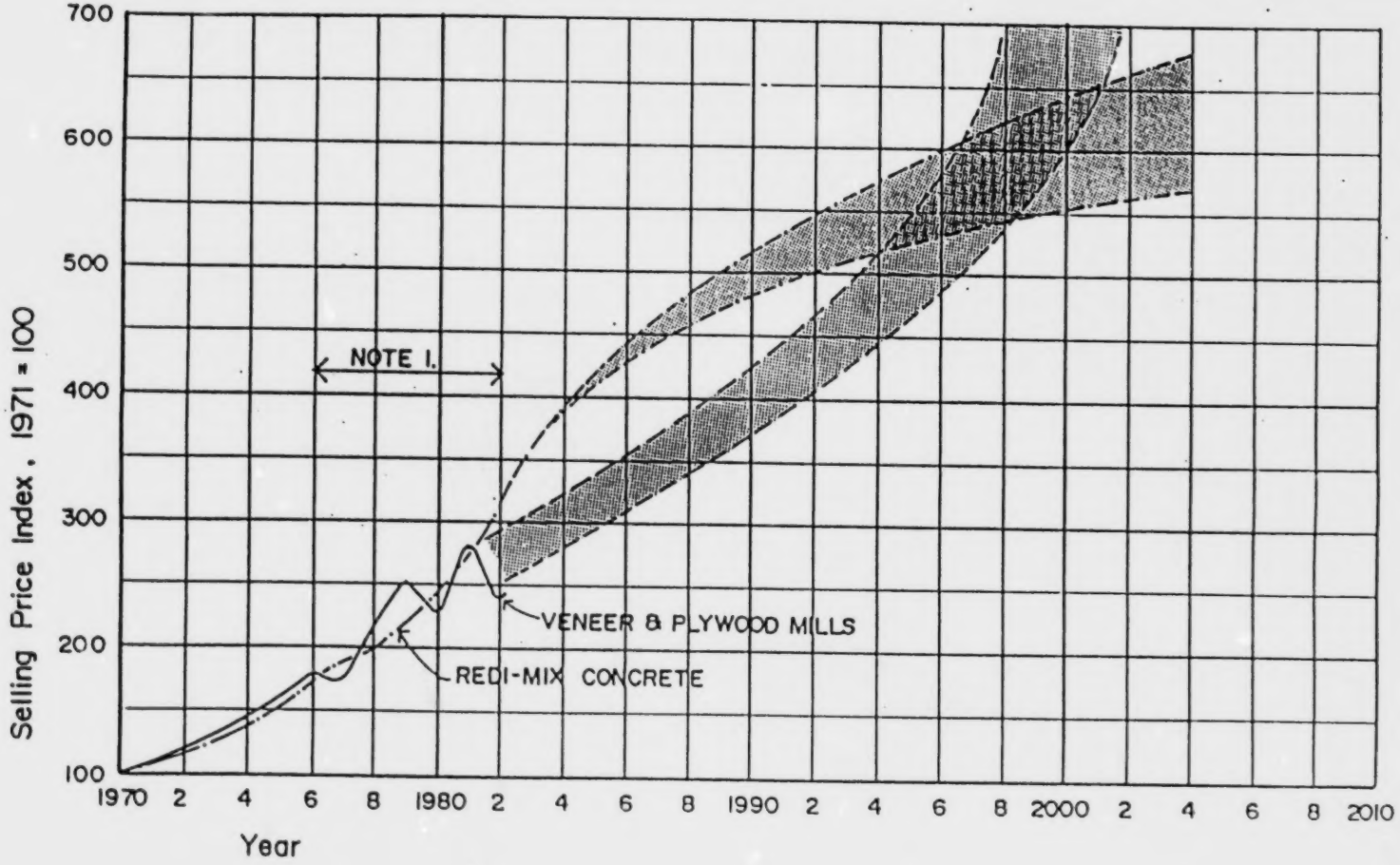
L.C.C.1.1. FUTURE FORECAST (WOOD):

The availability of forest products at current levels can not be to assumed to remain constant. Forest management methods practiced throughout Canada today do not adequately deal with the requirements for reforestation. According to an article written by Roy MacGregor, Editor of Today Magazine "of the 800,000 hectares of timber the industry harvests each year, a mere one-quarter is artificially replanted or seeded". Regeneration of the forest by natural causes accounts for an additional one-quarter of that which is cut annually. Therefore, only half of the cut forest products may return to be harvested again. Add to this statistic the effect of forest fires and insect invasion, and it can be seen that reforestation efforts must be dramatically improved in order to secure a future stable product base at a reasonable cost. In addition many of our special wood products are produced outside of the province.

L.C.C.1.2 FUTURE FORECAST (CONCRETE):

The production of concrete, unlike forest products, is not subject to the rapid depletion (and slow regeneration) of the resource base. The raw materials necessary for the production of cement are readily available in Alberta and in large supply. The additional component products of concrete production are also found in abundant supply in most locations. Thus, the cost of concrete supply has been and is more likely to be more stable and predictable, as compared to that of lumber products. Both products are subject to a production labour component which can be assumed as escalating at a similar rate.

5. SYSTEMS EVALUATION (CONTINUED)



COMPARITIVE SELLING PRICE INDEX GRAPH

NOTES: 1. SOURCE: INDUSTRY PRICE INDEXES, CAT. 62-011
STATISTICS CANADA

L.C.C.1.3. FUTURE PRODUCT COST PREDICTIONS:

The graphic projection of material prices shown on Figure 1, Page 30 is a theoretical prediction based on the actual price index figures by Statistics Canada for the years 1976 to 1982. It is readily apparent that the historical forest products prices are not as predictable as concrete, and forest products are more sensitive to market pressures. The current downward trend of prices for forest products can be attributed to recessionary effects on the housing market both in Canada and the United States.

The projected lumber prices shown on the graph is an attempt at predicting the impact of depleting forest resources and a growing future market place. Projected concrete prices follow an extrapolation of past historical data as well as reflecting the anticipated energy self-sufficiency in Canada and the subsequent decreasing escalation of the costs of producing cement. Assuming the above predictions are valid, forest products will, in time, be escalating at a rate greater than that of concrete products.

L.C.C.2. METHODS OF EVALUATION

L.C.C.2.1. GENERAL L.C.C. CRITERIA:

Life-cycle costing is a method of accounting which sums all significant costs of ownership of an item, system or building over a specified length of time. To reduce the complexity of the analysis, elements that are considered to be the same in each option being studied, are identified and removed thus creating a comparative analysis. All costs are converted to today's dollars by present-worth

5. SYSTEMS EVALUATION (CONTINUED)

L.C.C.2.2. LCC DATA BASE ASSUMPTIONS:

Life cycle costing calculations used throughout the study are based on the following data base assumptions:

I. LIFE CYCLE PERIOD

UCOPAN three story	30 years
UCOPAN one story	30 years
FULCRUM - TILT	30 years
Wood Frame	30 years
Conventional Concrete Structure	30 years

NOTE: The Life Cycle Period has been selected at 30 years for all building types in order to equalize the data base and to reflect a reasonable mortgage amortization period.

II. DISCOUNT RATE ---------- 15%

III. INFLATION RATE for Maintenance and Renewal Costs ---------- 10%

L.C.C.3. **COST ANALYSIS**

L.C.C.3.1. COST BREAKDOWN SUMMARY (MID-RISE STRUCTURE):

ITEM:	CONVENTIONAL CONCRETE STRUCTURE:	FULCRUM-TILT STRUCTURE:
FORMWORK	$ 266,000	$ 163,000
RENTAL OF FORMS	-	45,000 *
REINFORCING STEEL	83,000	106,800
CONVENTIONAL FRAMING	-	-
CONCRETE SUPPLY	95,000	76,500
CONCRETE PLACING	25,000	19,575
CONCRETE FINISHING	35,775	8,000
HOLLOW CORE FLOORING	-	60,000
SPECIAL TILT-LIFT HARDWARE	-	22,000
TOWER CRANE	43,600	-
MOBILE CRANE	-	20,000
CRANE OPERATOR	23,000	incl. in above
TOTAL INITIAL COSTS:	$ 571,375	$ 521,275
POTENTIAL SAVINGS:	$ 571,375 - $ 521-275 = $ 50,100.00 Say: $50,000	

* This price is based on the availability of standardized forms on a rental basis.

L.C.C.3.2. COST BREAKDOWN SUMMARY (LOW RISE STRUCTURE):

ITEM:	CONVENTIONAL WOOD FRAME STRUCTURE:	UCOPAN CONCRETE STRUCTURE:
FRAMING LABOUR	$ 37,500	$ 180,750
FRAMING MATERIAL	115,250	-
ROOFING	22,250	27,000
SIDING	43,250	9,750
DRYWALL & INSULATION	86,500	56,000
CONCRETE	9,000	77,775
STEEL FORMS	-	14,500
REINFORCING STEEL	-	36,250
CRANE TIME	7,750	37,000
CAULKING	3,250	25,500
TOTAL INITIAL COSTS:	$ 324,750	$ 464,525

POTENTIAL EXTRA INITIAL COSTS: $ 139,775
Say: $140,000

POTENTIAL EXTRA LIFE CYCLE COSTS: $ 112,300
Say: $113,000

L.C.C. **LIFE CYCLE COSTING & COST ANALYSIS**

L.C.C.3.3. FUTURE EXPENDITURES CONVENTIONAL WOOD FRAME:

		YEAR																												TOTAL N.P.V.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
MAINTENANCE	EXTERIOR - PAINTING I/C STAINING					4.7					4.7					4.7					4.7					4.7						
	INTERIOR - PAINTING		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		1.8		
	TOTAL YEARLY COST (£'1000)		1.8		1.8	4.7	1.8		1.8		3.5		1.8		1.8	4.7	1.8		1.8		3.5		1.8		1.8	4.7	1.8		1.8		
	DISCOUNTED CASH FLOW (N.P.V.)(£'1000)		1.4		1.0	3.0	1.1		1.1		6.1		1.0		1.6	2.7	1.4		1.2		3.3		1.0		1.7	1.5	1.5		1.1			136
CYCLIC RENEWAL	ROOFING															12.7															
	TOTAL YEARLY COST (£'1000)															12.7															
	DISCOUNTED CASH FLOW (N.P.V.)(£'1000)															6.5															6.5
INDEPENDANT FUTURE SUMS	INSURANCE	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
	TOTAL YEARLY COST (£'1000)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
	DISCOUNTED CASH FLOW (N.P.V.)(£'1000)	1.3	1.3	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	22.8
ENERGY COSTS	TOTAL YEARLY COST																														
	DISCOUNTED CASH FLOW (N.P.V.)																														
NET PRESENT VALUE (N.P.V.) OF ALL FUTURE EXPENDITURES (£'1000)																															163

CONVENTIONAL WOOD FRAME - LOW RISE

Figure 2

L.C.C. LIFE CYCLE COSTING & COST ANALYSIS

L.C.C.3.4. FUTURE EXPENDITURES - UCOPAN SYSTEM:

		YEAR																													TOTAL N.P.V.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
MAINTENANCE	EXTERIOR - CAULKING						7.0						7.0						7.0						7.0							
	- CLEANING (CONC.)															7.0															
	- ROOFING															6.0															
	INTERIOR - PAINTING.		3.7		3.7		3.7		3.7		4.7		3.7		3.7		3.7		3.7		4.7		3.7		3.7		3.7		3.7			
	TOTAL YEARLY COST ($'1000)		3.7		3.7		3.7		3.7		4.7		3.7		3.7	6.0	3.7		3.7		4.7		3.7		3.7		3.7		3.7			
	DISCOUNTED CASH FLOW (N.P.V.) ($'1000)		3.9		3.7		4.0		2.2		1.7		3.0		1.7	4.1	1.6		2.3		1.7		1.2		1.8		0.9		0.9			33.7
CYCLIC RENEWAL																															
	TOTAL YEARLY COST																														
	DISCOUNTED CASH FLOW (N.P.V.)																														
INDEPENDANT FUTURE SUMS	INSURANCE	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	TOTAL YEARLY COST ($'1000)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	DISCOUNTED CASH FLOW (N.P.V.) ($'1000)	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	17.6
ENERGY COSTS																															
	TOTAL YEARLY COST																														
	DISCOUNTED CASH FLOW (N.P.V.)																														
NET PRESENT VALUE (N.P.V.) OF ALL FUTURE EXPENDITURES ($'1000)																															51.6

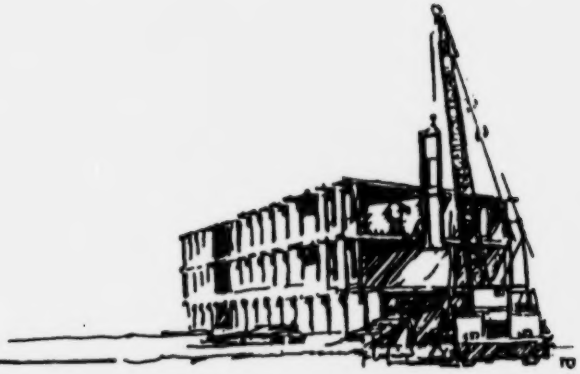
'UCOPAN' CONCRETE - LOW RISE

Figure 3.

L.C.C.3.5. TOTAL REAL COST SUMMARY TABLE:

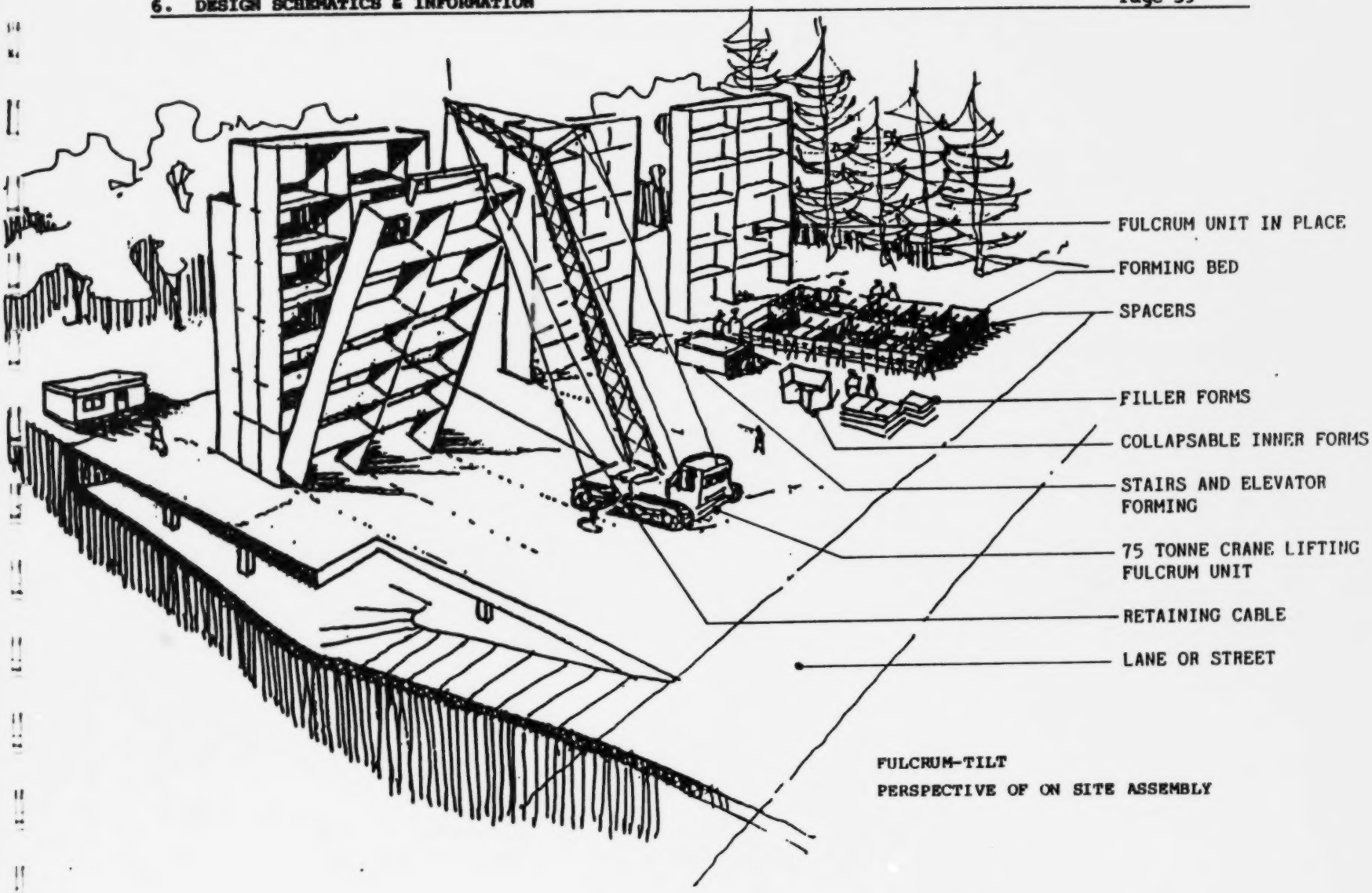
COST ELEMENT	ELEMENT BREAKDOWN	Conventional Wood Frame - Low Rise					'UCOPAN' Concrete - Low Rise					Conventional CIP Concrete - Mid Rise					FULCRUM TILT-UP' Concrete - Mid Rise				
		INITIAL COST	MAINT COST	CYCLIC RENEWAL	INDEP. FUTURE SUMS	ENERGY COSTS	INITIAL COST	MAINT COST	CYCLIC RENEWAL	INDEP. FUTURE SUMS	ENERGY COSTS	INITIAL COST	MAINT. COST	CYCLIC RENEWAL	INDEP. FUTURE SUMS	ENERGY COSTS	INITIAL COST	MAINT. COST	CYCLIC RENEWAL	INDEP. FUTURE SUMS	ENERGY COSTS
01 FOUNDATIONS	011 STANDARD FOUNDATIONS																				
	012 SPECIAL FDN CONDITIONS																10.0				
02 SUBSTRUCTURE	021 SLAB ON GRADE																				
	022 BASEMENT EXCAVATION																				
	023 BASEMENT WALLS																				
03 SUPERSTRUCTURE	031 FLOOR CONSTRUCTION	136.8					61.8					504.8					471.3				
	032 ROOF CONSTRUCTION						31.0														
	033 STAIR CONSTRUCTION																				
04 EXTERIOR CLOSURE	041 EXTERIOR WALLS	53.0	12.7				146.2	11.0													
	042 EXT DOORS & WINDOWS																				
05 ROOFING		22.2		6.5			22.0														
06 INTERIOR CONSTRUCTION	061 PARTITIONS	33.0	36.3				16.5	22.7													
	062 INTERIOR FINISHES																				
	063 SPECIALTIES																				
07 CONVEYING SYSTEMS																					
08 MECHANICAL	081 PLUMBING																				
	082 HVAC																				
	083 FIRE PROTECTION																				
	084 SPECIAL MECH SYSTEMS																				
09 ELECTRICAL	091 SERVICE & DISTRIBUTION																				
	092 LIGHTING & POWER																				
	093 SPECIAL ELEC SYSTEMS																				
10 GENERAL CONDITIONS - OVERHEAD & PROFIT		7.8			22.8		37.0			17.0		66.6					32.0				
11 EQUIPMENT	111 FIXED & MOVABLE EQUIP																				
	112 FURNISHINGS																				
	113 SPECIAL CONSTRUCTION																				
12 SITEWORK	121 SITE PREPARATION																				
	122 SITE IMPROVEMENTS																				
	123 SITE UTILITIES																				
	124 OFF-SITE WORK																				
13 FINANCING (AFFECTED BY CONSTRUCTION DURATION)																					
TOTAL INITIAL BUILDING COST (x $1000)		324.8	XXX	XXX	XXX	XXX	464.5	XXX	XXX	XXX	XXX	571.4	XXX	XXX	XXX	XXX	571.3	XXX	XXX	XXX	XXX
NET PRESENT VALUE (N.P.V.) (x $1000)		XXX	49.6	6.5	22.8		XXX	33.7		17.0		XXX					XXX				
TOTAL REAL COST (N.P.V. + INITIAL COST)		$ 403,700 [1]					$ 516,000 [1]														

Figure 4.



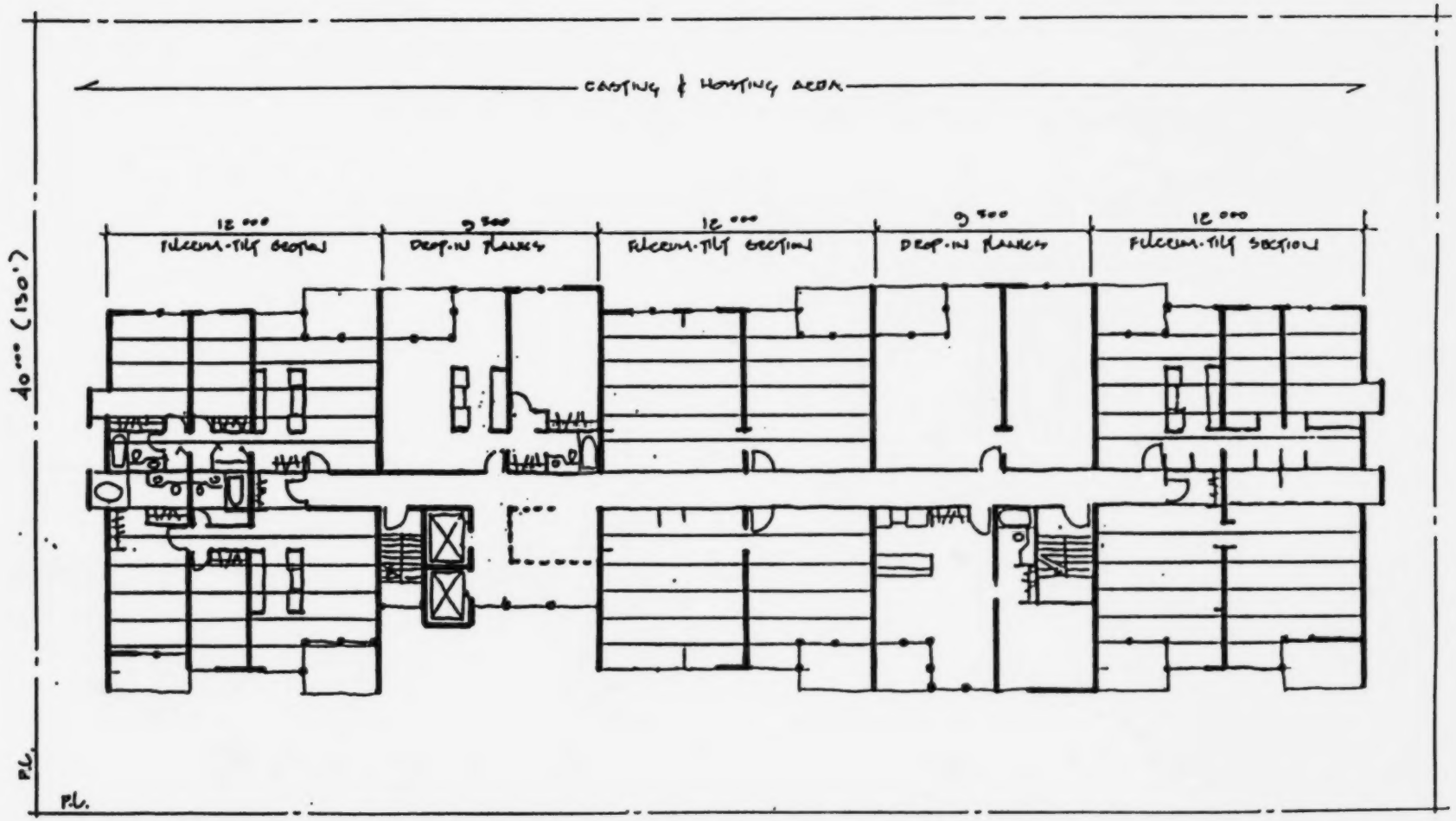
OUTLINE SPECIFICATION -- FULCRUM/TILT

Foundations:	Conventional cast in place parking garage.
Floors:	FULCRUM - TILT sections and precast plank, "feathered" grouting at joints.
Walls, exterior:	End walls -- FULCRUM - TILT with rigid insulation (62 mm) glued on, stucco finish. Other walls (front and rear elevations) -- conventional infill (dry-wall, steel stud, vapour barrier, bottom insulation, drywall, stucco or facebrick).
Walls, interior:	FULCRUM - TILT walls -- "Spraytex" on concrete, caulked joints. Other walls -- conventional drywall on steel studs.
Roof:	Conventional flat roof.
Balcony Railings:	Conventional (aluminum and steel stud / drywall / stucco combination).
Windows / Doors:	Conventional



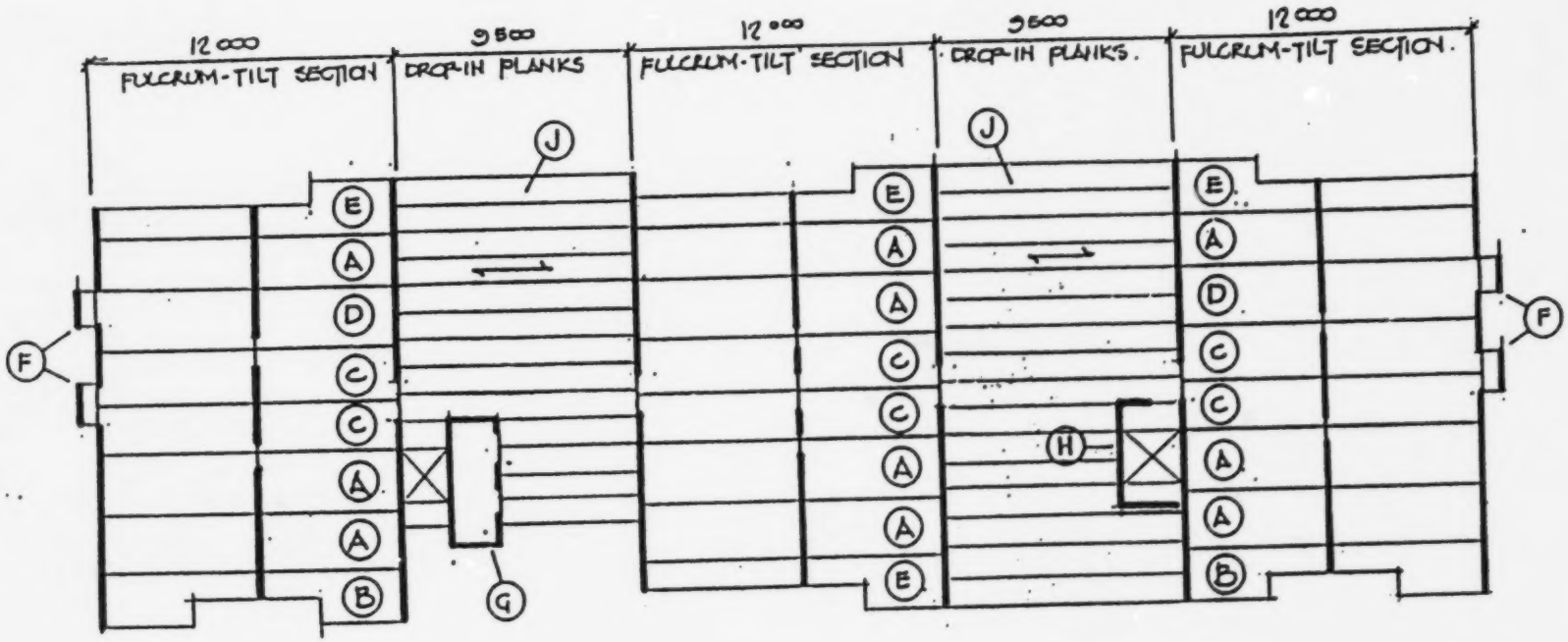
FULCRUM-TILT
PERSPECTIVE OF ON SITE ASSEMBLY

Fulcrum-Tilt
Six Storey Mid-rise
Typical Elevation



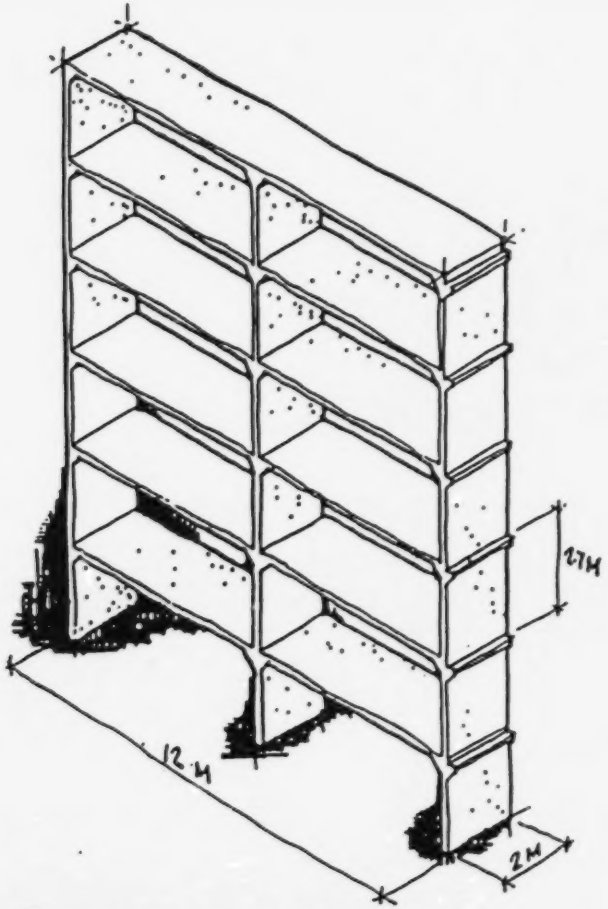
Fulcrum-Tilt
Six Storey Mid-rise
Typical Floor Plan

6. DESIGN SCHEMATICS & INFORMATION

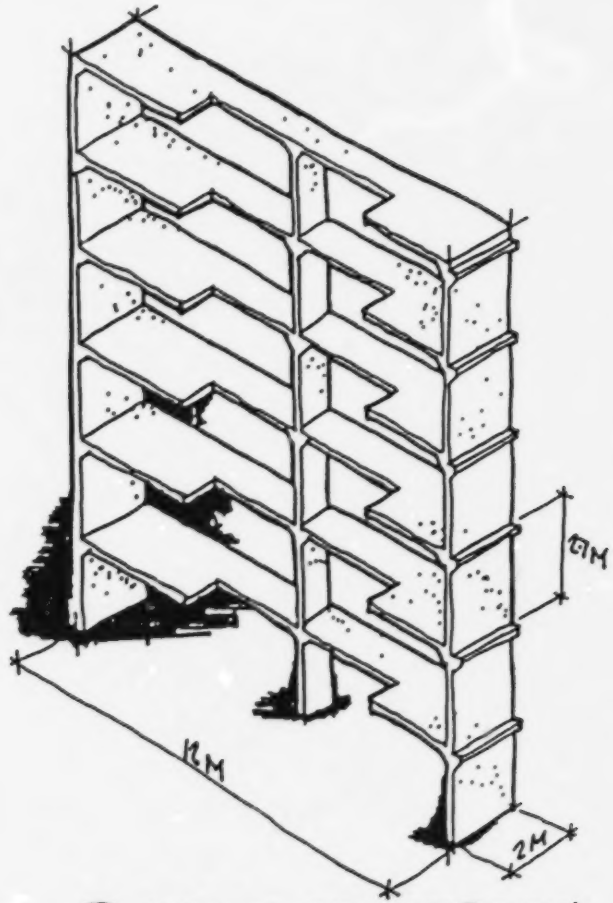


Fulcrum-Tilt
Structural Components
Key Plan

6. DESIGN SCHEMATICS & INFORMATION

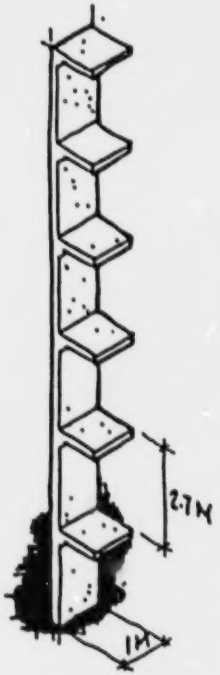


(A) TYPICAL FULCRUM-TILT UNIT

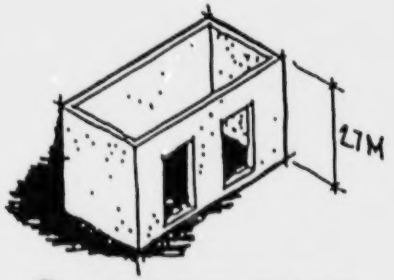


(B) BALCONY UNIT (©D©E SIMILAR)

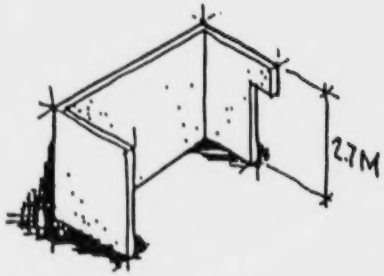
Fulcrum-Tilt
Structural Components



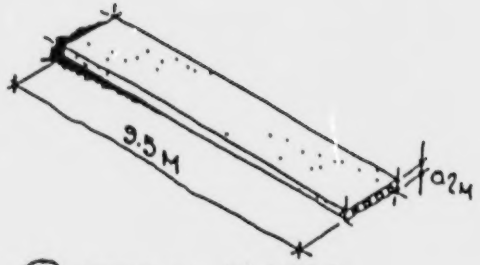
(F) BAY WINDOW



(G) ELEVATOR SHAFT.

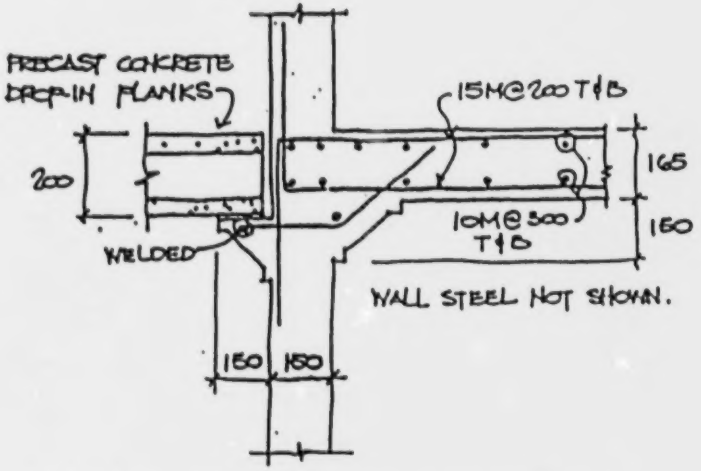


(H) STAIR UNIT

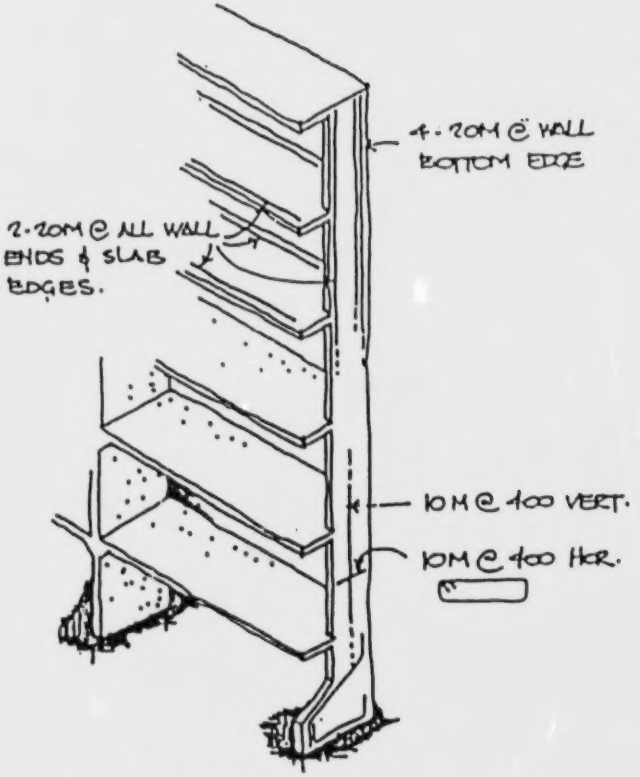


(J) DROP IN PLANKS

Fulcrum-Tilt
Structural Components



TYPICAL FLOOR & WALL CONNECTION



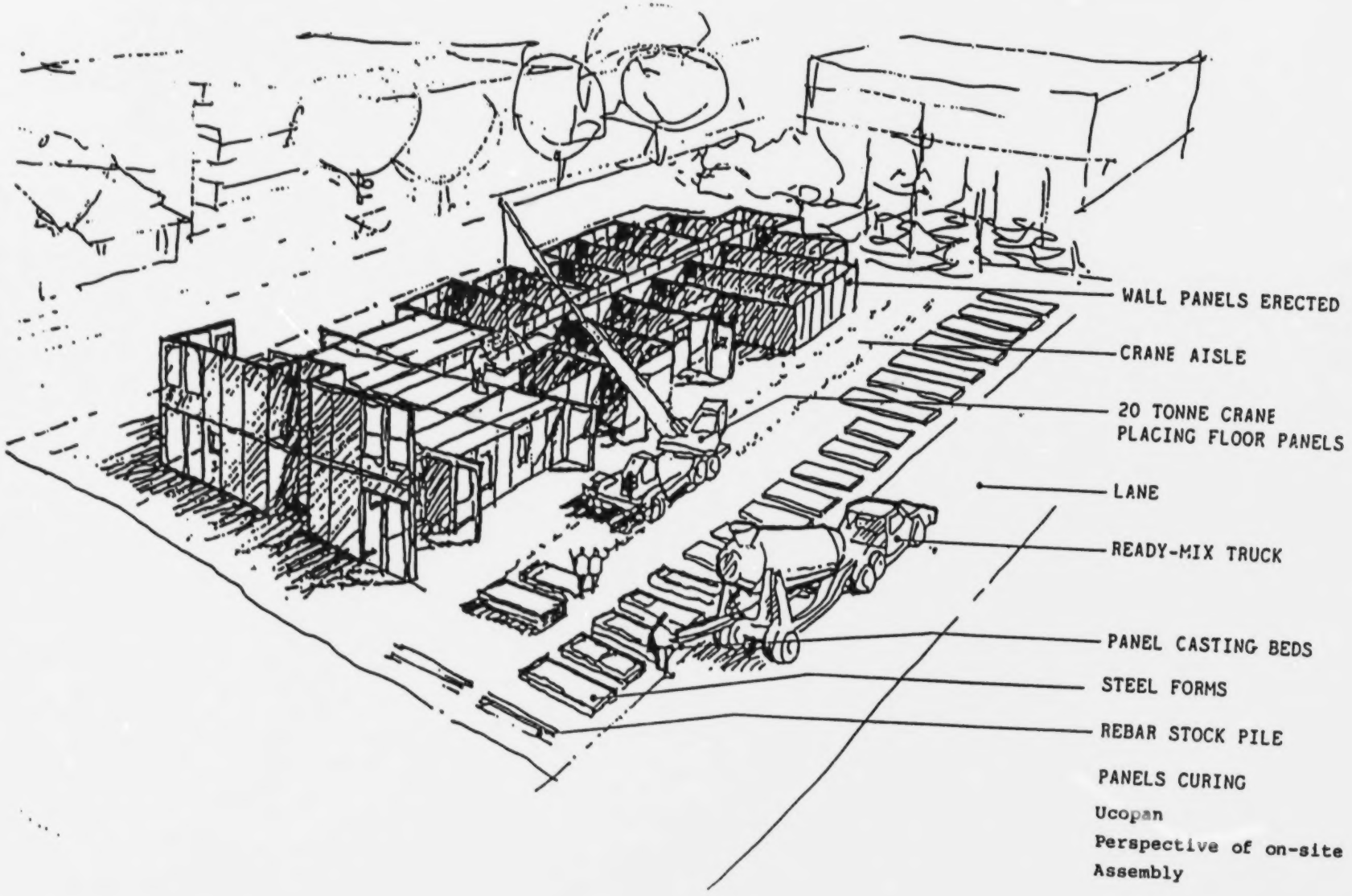
REINFORCING DETAIL

Fulcrum-Tilt
Structural Components
Reinforcing

OUTLINE SPECIFICATION -- UCOPAN / 3 STOREY

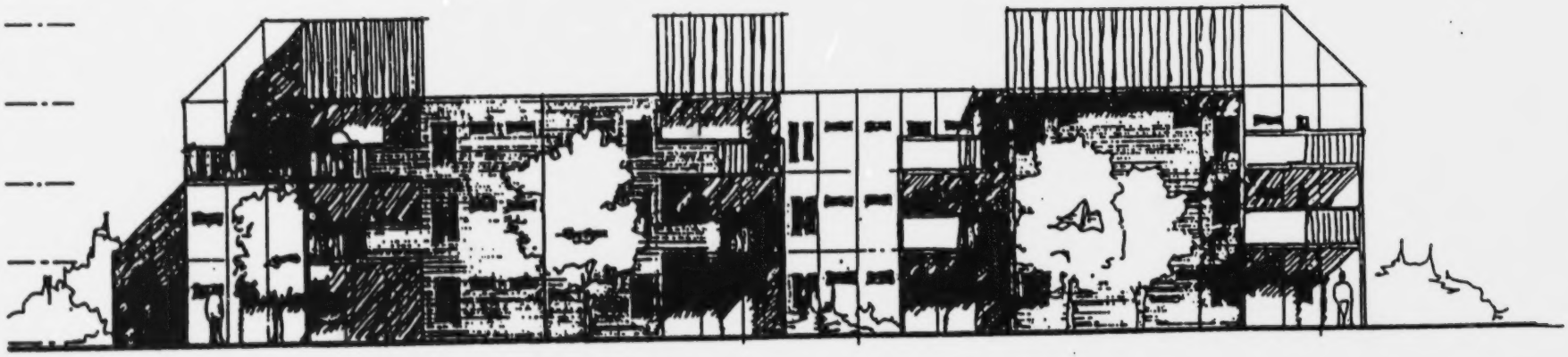
Foundations:	Conventional cast-in-place concrete basement walls. Conventional cast-in-place concrete basement floor slab. Ucopan bearing cross walls.
Floors:	75 mm thick UCOPAN panels, 19 mm topping and grouted joints (no ceilings, only untreated undersides of panels).
Walls, exterior, UCOPAN:	75 mm thick UCOPAN, 75 mm batt insulation, vapour barrier, drywall, paint.
Walls, exterior, Other:	100 mm horizontal siding (wood), steel stud, 87 mm batt insulation, vapour barrier, drywall and paint.
Walls, interior, bearing,	50% of wall area 75 mm thick UCOPAN panels, painted, (joints caulked on party walls). 50% of wall area 75 mm thick UCOPAN panels, strapped, drywalled and painted.
Walls, interior, Other:	Drywall both sides of metal studs.
Roof:	75 mm thick UCOPAN panels, conventional membrane and insulation. Sloped metal roofing, on insulation, on UCOPAN panels.

Balcony Railings:	Conventional aluminum pickets (50%), and steel stud/ drywall/ horizontal siding (50%).
Balcony Floors:	Sandblasted UCOPAN panels.
Balcony Supports:	UCOPAN "open" frames (similar to "door" panels).



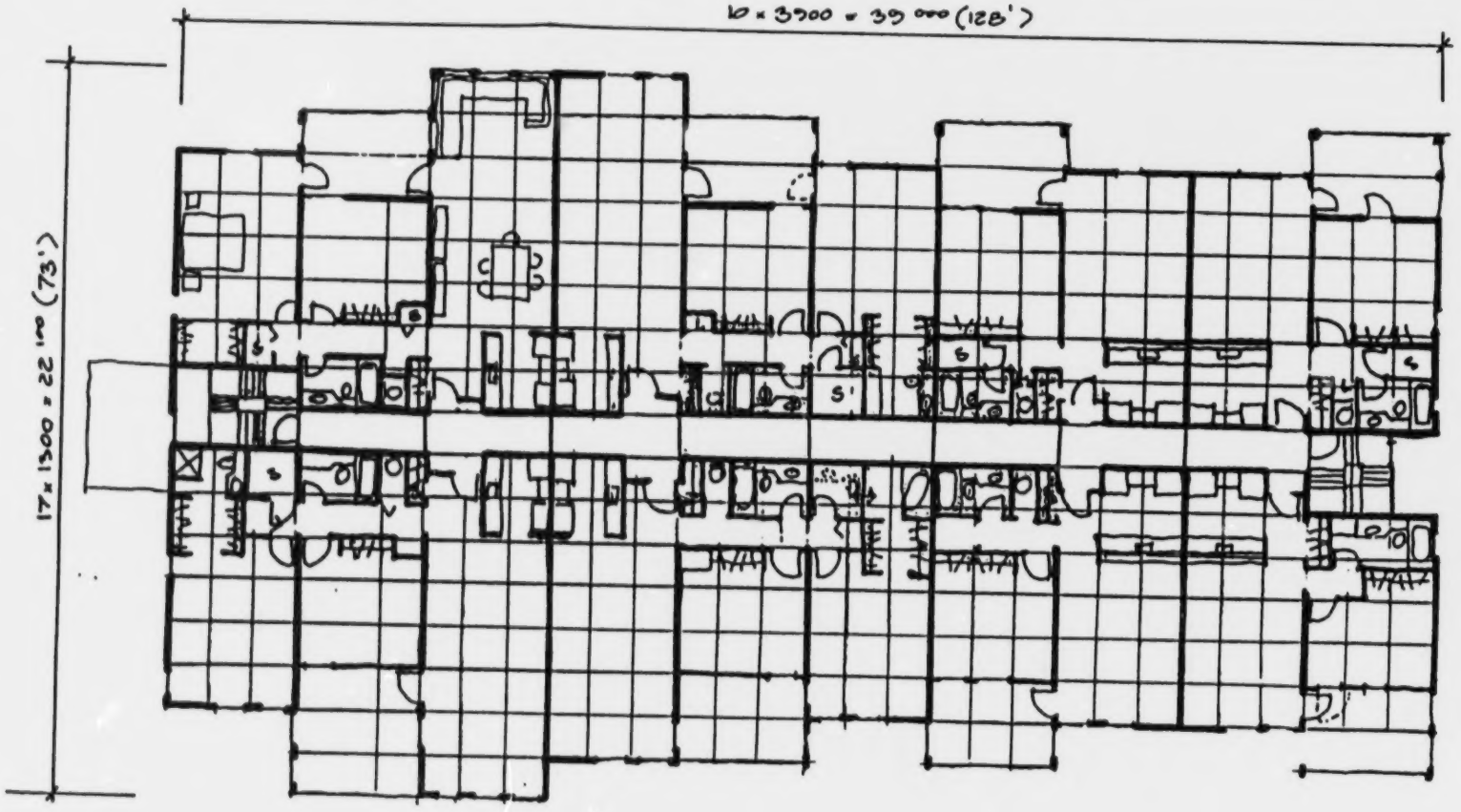
Ucopan

Perspective of on-site Assembly



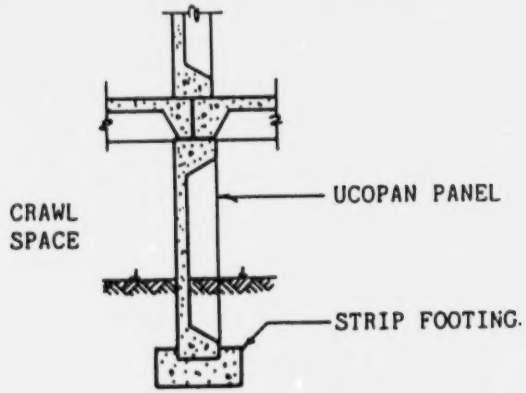
Ucopan
3 Storey Walk-Up
Typical Elevation

6. DESIGN SCHEMATICS & INFORMATION



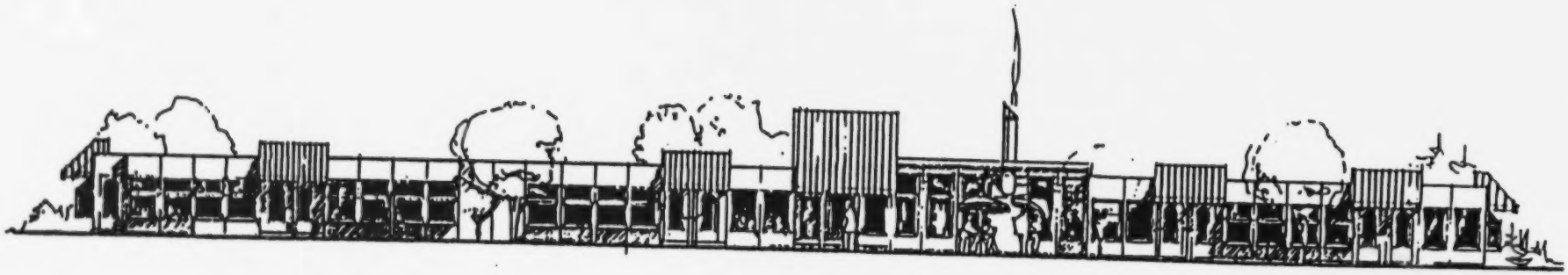
Ucopan
3 Storey Walk-Up
Typical Floor Plan

OUTLINE SPECIFICATION - UCOPAN / 1 - STOREY (SENIORS)

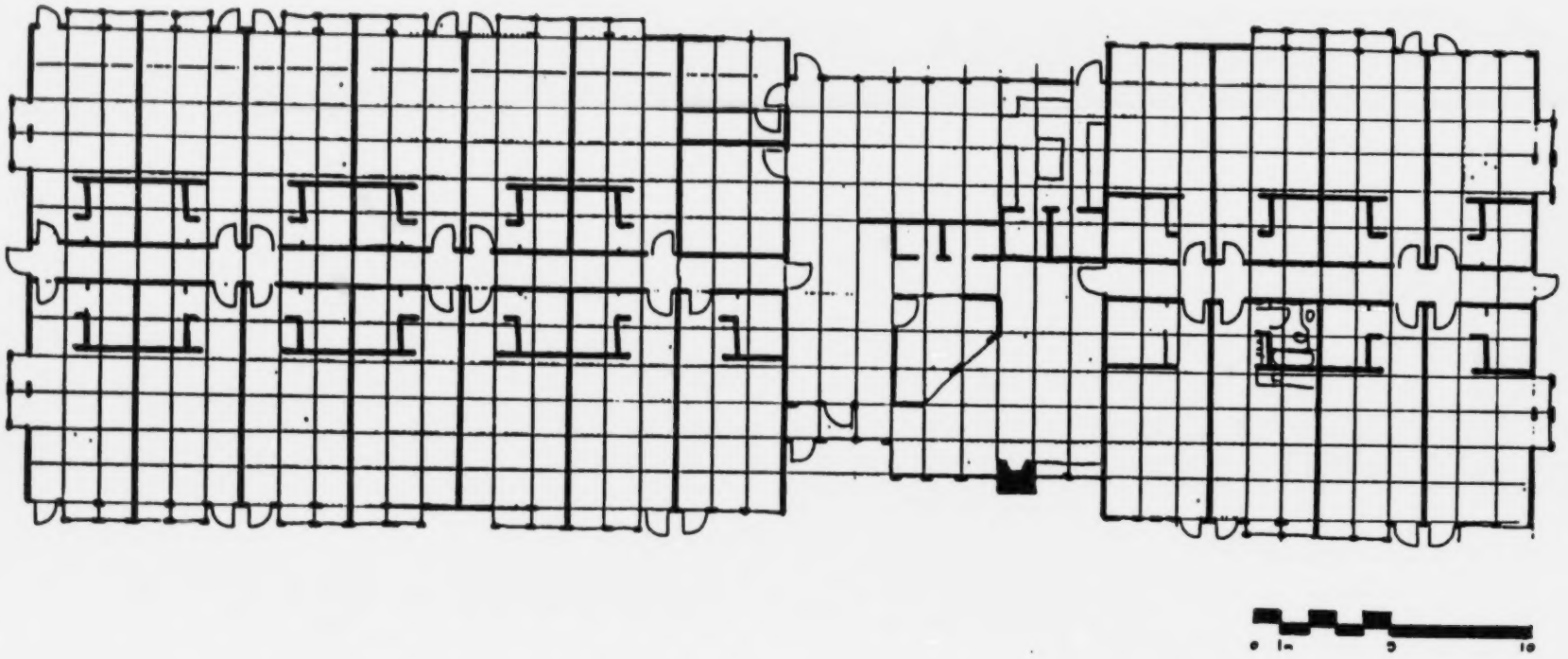


Foundations:	Cast-in place footings.
Floors:	75 mm thick UCOPAN panels, 19 mm thick topping and grouted joints.
Walls, exterior:	75 mm thick UCOPAN, 75 mm batt insulation, vapour barrier, drywall, paint.
Walls, interior, bearing, cross-walls:	75 mm thick UCOPAN panels, painted, joints caulked.

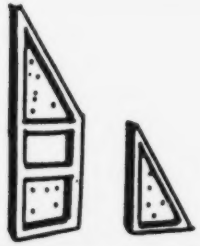
Walls, interior, other:	Drywall both sides of metal studs.
Roof:	Over "living units" section, 75 mm thick Ucopan panels, conventional membrane and insulation. Sloped metal roofing on metal framing over entries. Over "common" section, precast beams, Ucopan panels. (Sloped metal roofing as in about 50% of this roof area.)
Windows / Doors:	Conventional. (No sliding patio doors.)

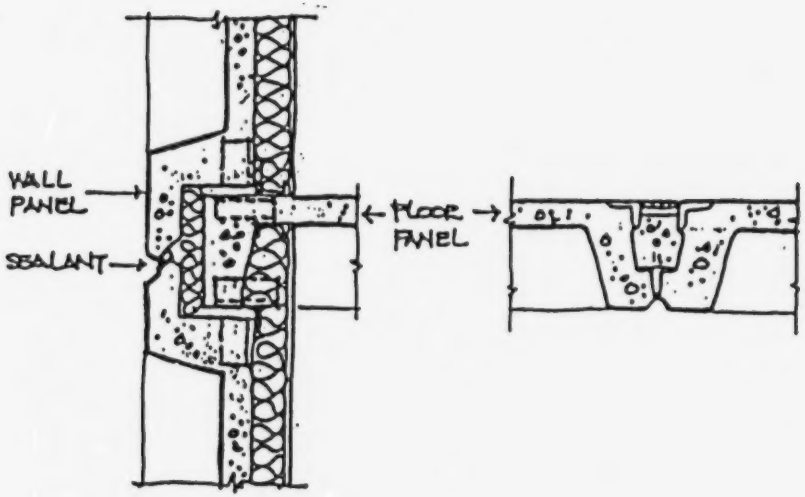


Ucopan
Senior's Lodge
Typical Elevation



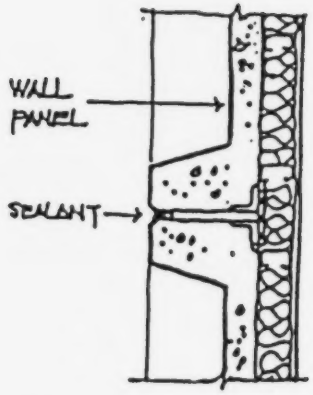
Ucopan
Senior's Lodge
Typical Floor Plan

BASIC FORM	Variations
Floor and Roof Panels	None required (could possibly use specially "textured" panels for balconies).
Walls	Window Panel - Low Sill Window Panel - High Sill Door/ Support Window Panel - Clere-storey
Stairs	4-Riser infill pieces (Other stair configurations are possible, of course)
Gable Infills	Right Hand and Left Hand Versions 



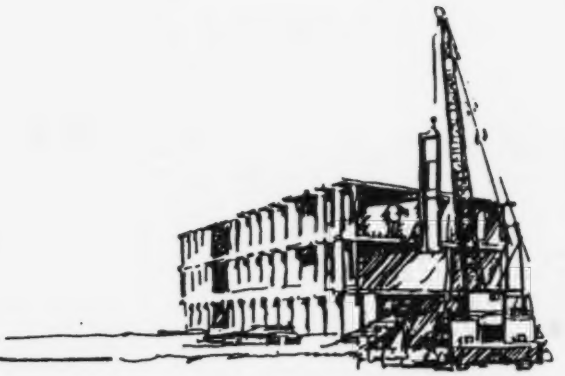
FLOOR & WALL PANEL CONNECTION
VERTICAL SECTION

FLOOR PANEL CON.



WALL PANEL CONNECTION
PLAN SECTION.

Ucopan
Panel Connection Details



7.1 CONCLUSIONS:

The Architectural, Structural, and to a lesser degree, the Cost Analysis evaluations have indicated that both building systems are totally feasible from the point of view of providing pleasant, functional living units, while meeting all accepted structural engineering standards and appear within acceptable cost parameters noting predicted future trends. Further, it was found that the construction techniques required were practicable and did not require the development of any new technology or materials in order to implement such projects. Architectural flexibility in both schemes allows variety in unit planning and massing, as well as allowing the development of attractive and interesting exterior elevation treatments. Generally both building systems will provide a better quality living environment and a higher quality structure than the traditional poured-in-place or wood frame building systems.

Our study of the cost projections for timber products versus concrete materials indicates that towards the year 2000, there may be a significant increase in lumber prices relative to concrete costs. If this prediction is correct, there are tangible benefits to the UCOPAN system as opposed to a wood frame structure. However, it is only possible at this time to speculate on the over-all impact this may have on the cost viability of the system.

The UCOPAN system will have a modular appearance due to the standardization of panels. This, however, can be moderated with the introduction of different materials and roof treatments as shown on the elevations. Site limitations for the UCOPAN system do not

appear overly restrictive for potential development. The single storey Senior Citizen structure would not appear to be viable unless it was coupled with a larger development utilizing the same structural components. Both building systems do lend themselves to Senior Citizen buildings of three or more stories.

Structurally, the UCOPAN system presents no unusual engineering problems, but does rely on the availability of steel forms for panel production. Cost analysis of the UCOPAN system indicates that with current material and labour costs in Alberta, the system does not appear to be economically feasible at this time when compared to frame construction; even after taking into account the Life Cycle Cost difference between the systems.

The FULCRUM-TILT building will not differ noticeably in appearance from a traditional poured-in-place structure as identical exterior in-fill materials can be used. This system does however have site limitations to accommodate the required casting area, but will meet the restrictions of most sites suitable for mid-rise development. The FULCRUM-TILT system will require a more detailed structural analysis and the possiblity of custom designed framework and lifting hardware. These factors must be recognized, but should not be considered detrimental to the development of the system. The cost analysis for the FULCRUM-TILT system study project indicates that there is a potential saving in the structural element of approximately 10 percent, with no change in the Life Cycle Cost of the structure.

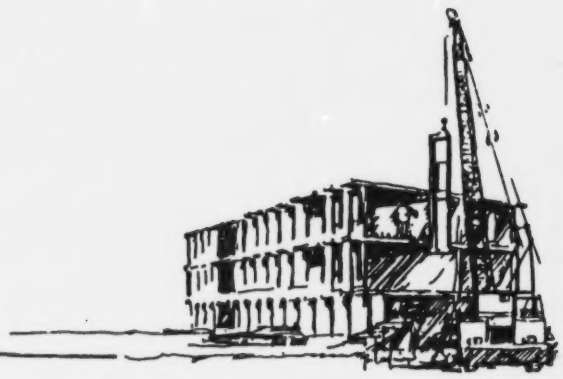
7.2 RECOMMENDATIONS:

Two projects utilizing the H-Frame, Maxi-Panel and H-Module elements of the UCOPAN system have been completed. The projects would be ideal as case histories to evaluate the merits of the large scale UCOPAN elements. This exercise could be completed in a follow-up study incorporating not only the above-mentioned areas, but also investigation of the cost saving possibilities of coordinating and integrating standard building elements within the system.

In light of the cost analysis of the FULCRUM-TILT system, we would recommend that the Planning and Research Department initiate action to encourage a Pilot Project. This might be accomplished on a planned mid-rise project for Alberta Housing Corporation, perhaps in conjunction with a developer, construction management firm or General Contractor.

Further, it appears that additional efficiencies can be achieved with this system via the interface with other building elements. the extent and impact of such interface ideas would be recommended as an integral part of a Pilot Project.

In closing, it appears that use of site precast systems is only feasible, at this time, for developments which call for non-combustible construction such as cast-in-place concrete, plant precast concrete or structural steel structures. Specialized cases may exist where wood frame construction materials and the related labour skills are not applicable or readily available affording the opportunity to utilize site precast systems.



8. APPENDICES

APPENDIX 'A' 1. Fulcrum-Tilt Patent

2. Ucopan Patent

APPENDIX 'B' Applicable Standards for Design and Construction of Site Precast Building Structures

APPENDIX 'C' Forest Renewal and Projected Lumber Shortfalls

APPENDIX 'A'

"FULCRUM-TILT PATENT"

United States Patent [19]
Reale

[11] 3,940,902
[45] Mar. 2, 1976

[54] FULCRUM TILT BUILDING SYSTEM

[76] Inventor: Lucio V. Reale, 1311 Grenade St., Chambly, Quebec, Canada

[22] Filed: Apr. 1, 1974

[21] Appl. No.: 457,082

[52] U.S. Cl. 52/745; 52/79; 52/236
[51] Int. Cl.² E04G 21/00
[58] Field of Search 52/79, 236, 745, 167

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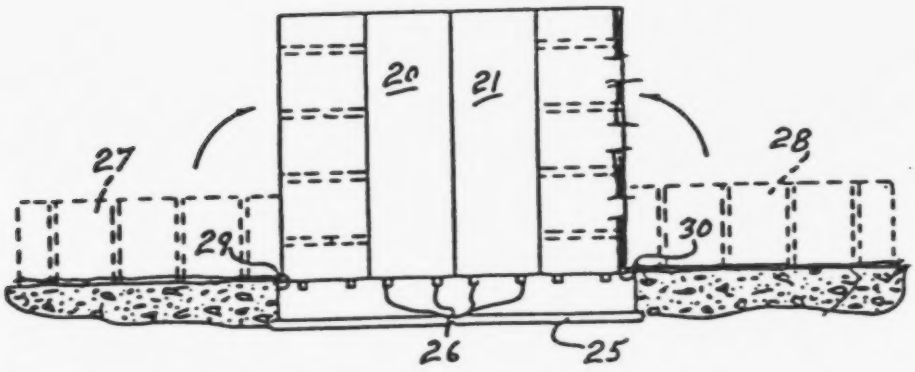
Primary Examiner—Ernest R. Purser
Assistant Examiner—Henry Raduazo
Attorney, Agent, or Firm—Larson, Taylor & Hinds

[57] ABSTRACT

A method of constructing buildings is disclosed wherein a multicellular monolithic structure is formed with walls and future floors all in a vertical plane. The walls may be formed from concrete or other laminate material. The structure is then tilted about tilt points along a tilt line which is retained in a V-groove attached to a base until the structure reaches a vertical location. After the tilting step the structure is levelled by means of jacks. Wedges are inserted to support the structure and the jacks are removed. Several structures may be assembled to form a building. Cantilever walls may be added which join together to form a corridor or hall between structures.

7 Claims, 10 Drawing Figures



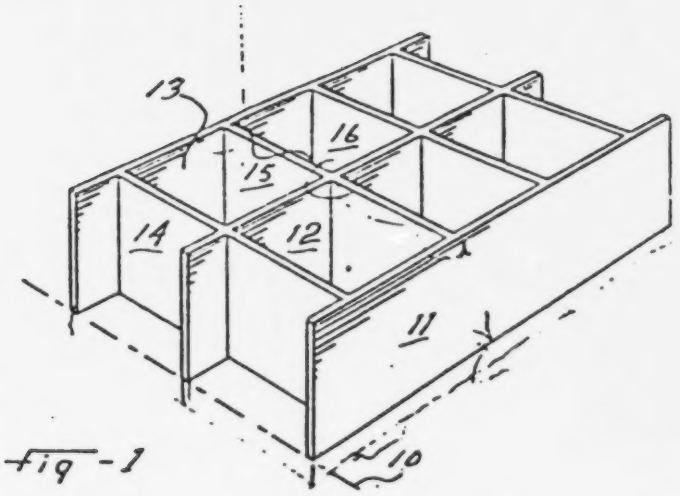


fig-1

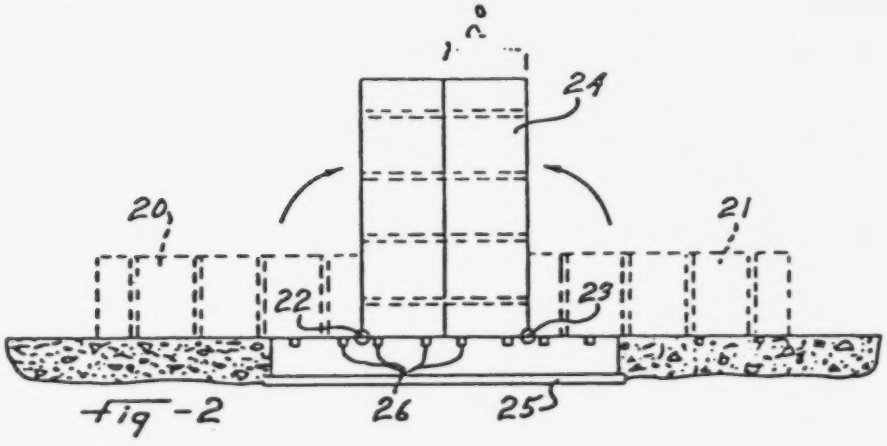


fig-2

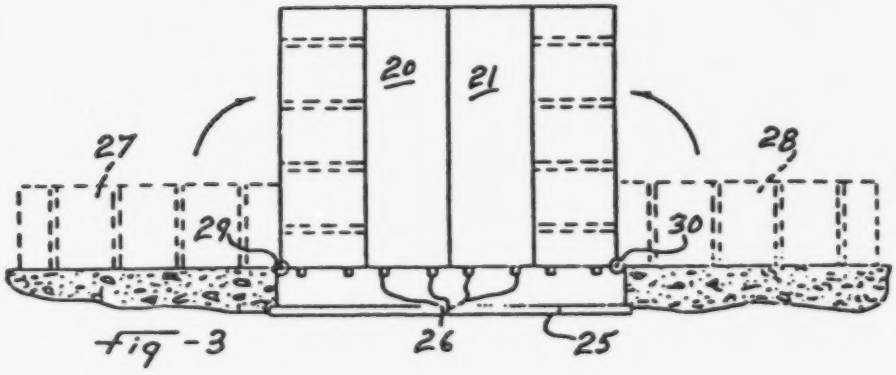


fig-3

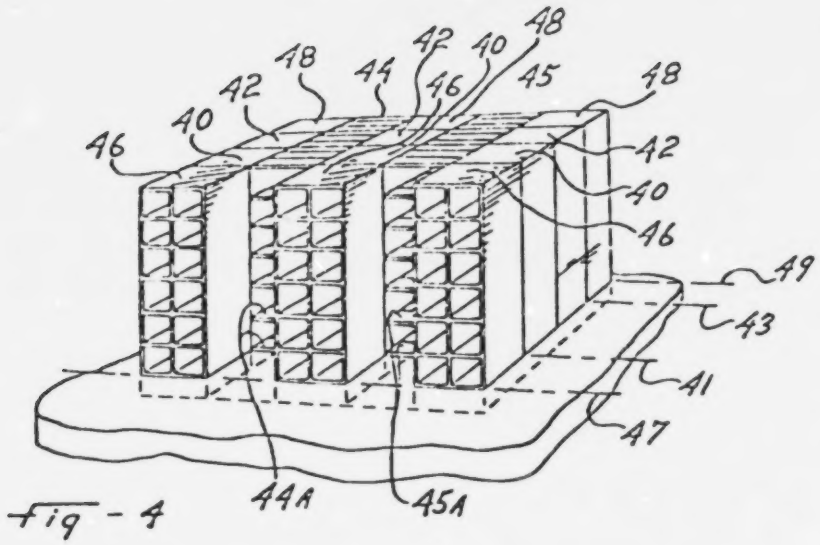


fig - 4

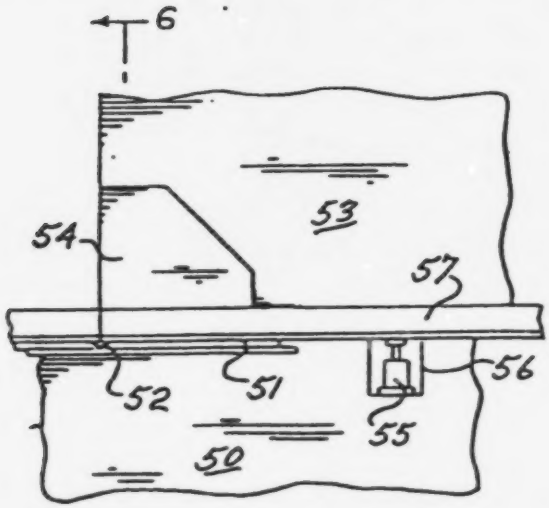


fig - 5

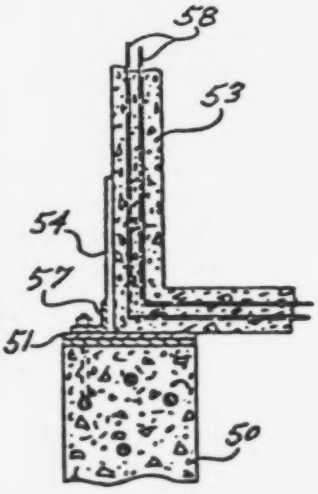


fig - 6

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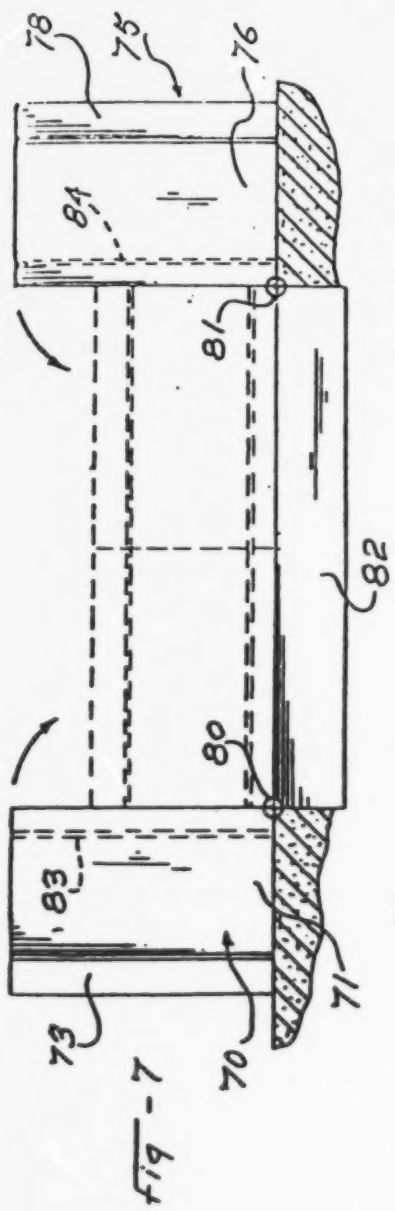
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Fig - 7

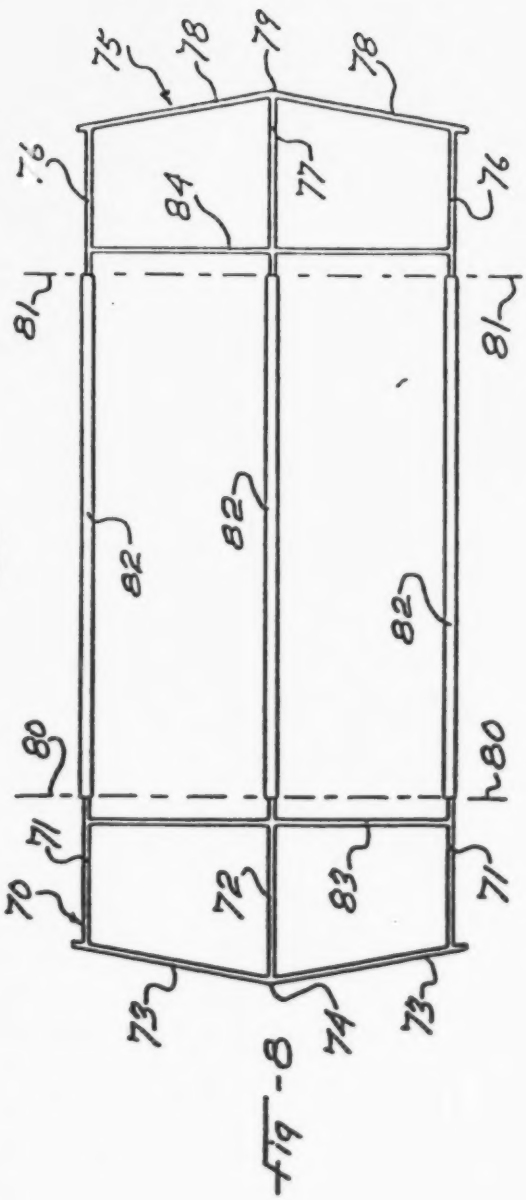
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Fig - 8

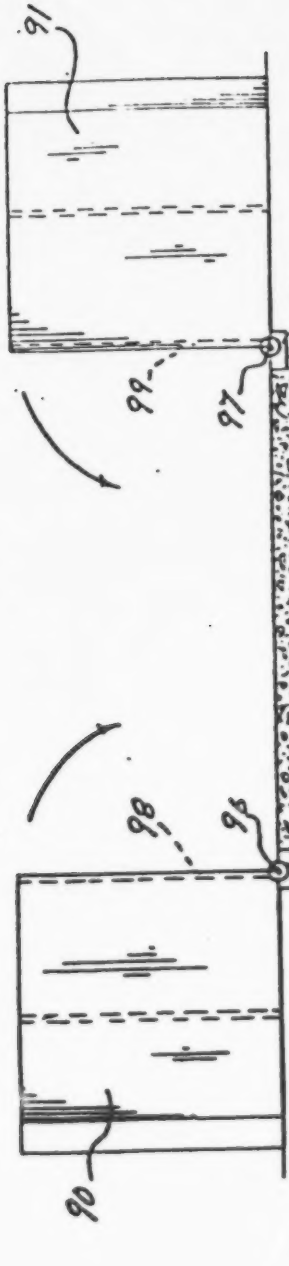
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Fig - 9

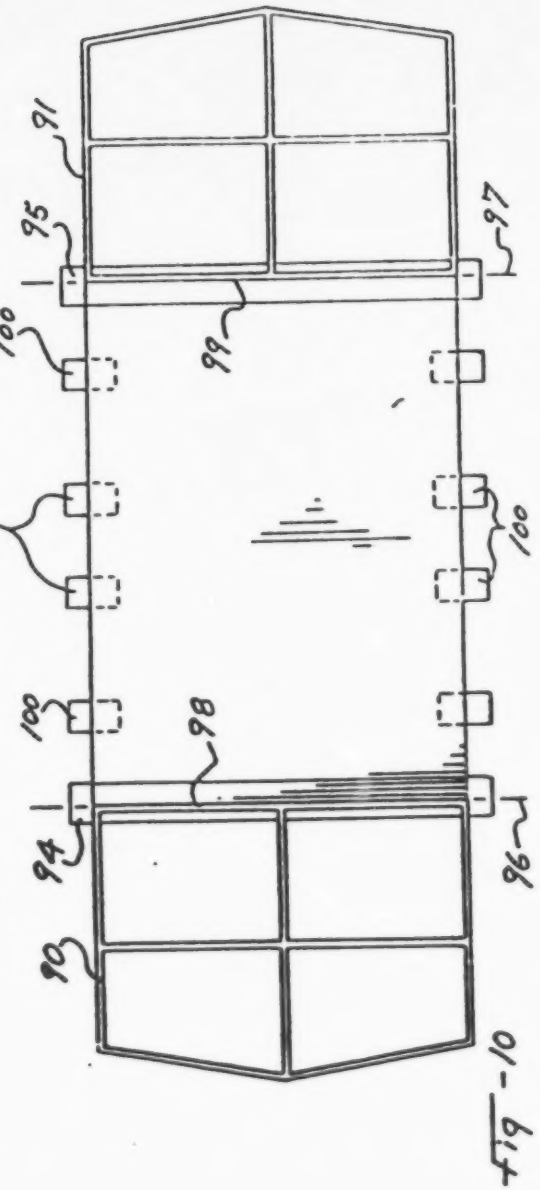
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Fig - 10

FULCRUM TILT BUILDING SYSTEM

This invention relates to a method for constructing buildings, and more particularly, to a method of forming a multicellular, monolithic structure with vertical walls and floor slabs, tilting the structure to an upright position and adding the end walls.

There are a number of well known methods for constructing buildings, such as apartments, office blocks, etc. Most of these types of buildings require a concrete floor, the floor either being poured or cast in place or, alternatively, pre-fabricated or pre-cast and erected in panels or blocks as the building rises. In some cases, a complete building is formed of concrete panels or units which are pre-cast; the units may be formed of single cell structural sections of one or more stories, which are mounted one upon the other to form the building. Alternatively, they may be panels which are assembled to form walls and floors; or another method, perhaps the most common method, is constructing a building by making forms and pouring the walls and then the floor on top of the walls as the building rises. Other methods exist for constructing buildings, such as casting concrete panels or units on ground level and then lifting them up and assembling them in position. Some buildings have steel structures to support the floors; in such buildings the steel is first erected, and then pre-cast concrete slabs are assembled on the steel beams or alternatively forms are positioned for pouring a concrete slab in place. Masonry brick walls may sometimes be used for bearing walls but not generally for floors.

In conventional construction methods, one commences with the foundation walls and works up. If the floors are being cast in place, forms have to be positioned on each floor. The forms may be reausable but they have to be well supported to prevent the liquid concrete spilling and causing accidents. If the walls and floors are pre-cast concrete slabs, then when they are erected in place one is faced with moving a large number of components which requires the continual use of hoists or cranes and consequently a high labour content with this method. All these conventional methods of concrete construction include cold joint forming between the structural components.

It is an object of the present invention to provide a method for constructing a multi-cellular monolithic structure which does not require pouring concrete in flat horizontal floor panels, neither does it require the assembly of the building in many components.

To obtain this and other objects of the present invention, the method of constructing should be efficient and economical; it should meet all architectural, structural, mechanical and construction requirements, and should be adaptable for various types of structures and designs. Such a building method should make the building simpler and more economical to build and preferably avoid the use of concrete forms that have to be moved and reused as the building rises.

The present invention includes a method of constructing a building comprising the steps of assembling at least one multi-cellular, monolithic structure in the horizontal plane having only vertical walls and floor slabs, tilting the structure about a tilt line to raise it to a vertical location, and levelling the structure after the tilting step.

The multicellular, monolithic structure is first formed at ground level with the walls and floors being in the vertical plane and then tilted about tilt points along a tilt line of the structure through 90° to the upright position to form the building structure. It is then necessary to finish the building by the construction of end walls, which may be curtain wall construction, masonry brick walls or other suitable types erected on site. A multicellular, monolithic structure has advantages over the single cell monolithic structure, as multicellular structures have only one wall between cells, whereas a single cell monolithic structure requires a wall around each cell. Thus there are two walls between cells in the single cell monolithic structure against only one wall between cells in a multicellular monolithic structure.

Another advantage of the multicellular, monolithic structure is strength. In a single cell monolithic structure, it is generally necessary to calculate bending moment using the $Wl^2/8$ formula for simple supported spans and, in view of the fact that each cell in the system is separate, the bending moment must be calculated individually. However, for the multicellular, monolithic structure, one can consider it as one component; thus the stresses may be calculated as extending over all the walls and floors in the structure with a considerable advantage in strength. This means that a reduced thickness of the concrete slab and a relative reduction of the steel area in the concrete may be obtained which consequently reduces the weight of the structure.

A further advantage of the present invention is apparent when concrete structures are being considered. Whatever method of forming is used to obtain a multicellular, monolithic structure, the concrete walls and slabs are all poured vertically.

These and other objects of the present invention will be apparent from the following detailed specifications and the accompanying drawings which illustrate embodiments of the invention:

FIG. 1 is a schematic perspective view of a multicellular, monolithic structure of the present invention.

FIG. 2 is a schematic elevational view of the fulcrum tilt system, with two opposing multicellular, monolithic structures, tilted from the horizontal to the vertical position.

FIG. 3 is a schematic elevational view of a continuation of the structure shown in FIG. 2 with two multicellular, monolithic structures tilted from outside the two existing erected monolithic structures.

FIG. 4 is a schematic perspective view of an erected building formed from multicellular, monolithic structures, which have been tilted into the vertical position.

FIG. 5 is an end view at the location of the fulcrum tilt showing a multicellular, monolithic structure in the upright position.

FIG. 6 is a cross-sectional elevational view through the side of a multicellular, monolithic structure adjacent the location of the fulcrum tilt showing a guide angle retaining the structure in the correct location after tilting to the upright position.

FIG. 7 is a side elevational view of a further embodiment of a multicellular, monolithic structure cast in two halves and then tilted to form a building.

FIG. 8 is a plan view of the embodiment shown in FIG. 7.

FIG. 9 is a side elevational view of yet another embodiment of a multicellular, monolithic structure cast in two halves and then tilted to form a building.

FIG. 10 is a plan view of the embodiment shown in FIG. 9.

Referring now to the drawings, a multicellular, monolithic structure is shown in FIG. 1, assembled about a fulcrum tilt line 10. The three vertical walls 11, 12 and 13 extend perpendicular from the tilt line 10. Between the vertical walls 11, 12 and 13 spaced apart to form rectangular cells are three further walls 14, 15 and 16. The walls are all integrally formed together, thus forming the multicellular, monolithic structure. The walls may be made from a number of known building materials, perhaps the most common today being concrete which is poured into forms with reinforcing steel in place to strengthen the walls. The concrete may be poured by a number of methods, such as a slip-form method, a removable and reversible form method, and others known to those skilled in the art. It is important that no cold joints occur in the structure as this reduces its strength.

Another method of constructing the multicellular, monolithic structure, such as that shown in FIG. 1, is according to my method shown in Canadian Pat. No. 887,175 which issued Nov. 30, 1971. This patent discloses the use of solid insulation as forms for pouring concrete, the insulation being held together by clips. The insulation may be removed after the concrete is cured or may remain as insulation for the building.

A slip-form method that may be used for the pouring of vertical concrete walls includes the use of a separate polyethylene sheet or other suitable plastic film that rests against the surface of the concrete as it cures and permits the slip-form to be slowly raised up, leaving the plastic film in place, against the surface of the concrete. The slip-form is preferably made from plywood with a smooth surface finish such as a plastic coating. A frame behind the plywood provides the necessary strength to support the plywood when the liquid concrete is poured into the form. The plastic film must have a low coefficient of friction with the slip-form in order for the slip-form to be raised leaving the film in place. The plastic film may be stripped from the concrete after the slip-form has been removed and the concrete has cured. To improve the coefficient of friction between the slip-form and the plastic film some form of oil or lubricating material may be used.

Another system that may be used is a band-roller system, where metal or plastic bands act as the form; these are supported by rollers at top and bottom, and may be slowly raised as the concrete is poured. The concrete at the bottom hardens and the bands are slowly raised to permit concrete to be poured in at the top before the surface of the concrete sets thus avoiding a cold joint. Such a system is essentially practical when a series of multicellular, monolithic concrete structures are to be prepared.

Regular slip-form methods are recognized as being capable of extruding vertical concrete walls having a thickness of at least eight inches. If the thickness is less than 8 inches, then the friction forces due to the weight of concrete against the slip-form creates problems in separating the slip-form from the concrete. Slip-form panels are preferably made of three-fourths inch plywood and are mounted on platforms which may be raised and lowered as a whole by means of hydraulic jacks. By the use of a thin film of plastic such as polyethylene, the thickness of the walls may be considerably reduced as the plastic film against the concrete surface reduces the friction between the slip-form and the plastic film, the plastic film remaining on the concrete. By this method, vertical walls having a thickness of less than six inches may be extruded satisfactorily.

Other materials than concrete may be used to construct the multicellular, monolithic structure; these include wood or plastic laminates of sandwich type construction, extruded foam with wood, metal or plastic reinforcing, and other new light weight building materials now being experimented with. It is important, however, that whatever materials are used the layers or other materials must all be firmly joined together to form the monolithic structure. Referring again to Fig. 1, the structure is erected by tilting it about the tilt line 10. When it is in the upright position, the walls 11, 12, 13 become the transverse bearing walls of the structure, the walls 14, 15, 16 become the floors of each storey, and in the case of the top floor 16, perhaps the roof of the building. It is not essential that walls 14, 15 and 16 are only located between the walls 11, 12 and 13. Extensions from walls 14, 15 and 16 may protrude beyond the walls and floor slabs so that they become cantilevered floor sections suitable for balconies or used in joining two or more structures together to form halls or corridors. It will be apparent to those skilled in the art that the walls need not necessarily be equidistant apart, nor need the rectangular cells be the same size. In this manner, the transverse bearing walls may be spaced to conform to desired architectural layouts. Corridors, halls, staircases and rooms may be incorporated within the structure and if desired the finishing of the walls and floors may be incorporated to satisfy the architectural finishing requirements before tilting the structure to its vertical location. Once the structure has been tilted to its vertical location, additional walls may be required at each end. If the structure is made in two halves, a second tilt line is spaced apart from the first tilt line such that when the second multicellular, monolithic structure is tilted into its vertical location, it mates with the first structure. The end walls and intermediate walls of the two structures may be curtain walls, glazed or pre-cast, and are placed in position where necessary. Balconies may be added if desired. In some cases a space may exist between two adjacent structures and this may be filled by means of pre-cast concrete panels, which form floors and other connecting walls. The sectional depth and height of a multicellular, monolithic structure varies depending on the site and architectural requirements. It is to be appreciated that the structure must be designed so that when lifted about its top corner it does not collapse and the structure at the fulcrum tilt line must have sufficient strength to take the load of the structure as it is raised. Similarly, one must consider the capacity and boom height of the crane or cranes required to raise the structure to its vertical location. These two factors restrict the size of the structure. The width and thickness of walls and floors have also to be taken into account to ensure they can be formed and have sufficient strength. The type of concrete to be used is equally important; if a light weight concrete is used, it may be possible to form five stories in one multicellular, monolithic structure which may then be tilted to its vertical location.

FIG. 2 shows two multicellular, monolithic structures 20 and 21 each having four stories which are assembled in a horizontal position and then tilted about their appropriate fulcrum tilt lines 22 and 23 into a vertical location where they mate to form a single building 24. The foundation walls 25 are formed before tilting the structures into their vertical location and contain

strengthened positions at the tilt lines 22 and 23 and pockets 26 in the walls 25 for jacks so the structures may be levelled after they have been raised. Once the first two structures 20 and 21 are erected, as shown in FIG. 2, two farther multicellular, monolithic structures 27 and 28 are assembled in the horizontal position, as shown in FIG. 3 and then tilted about fulcrum tilt lines 29 and 30 into a vertical location, thus increasing the size of the building. In the same way, the foundation walls 25 have strengthened positions at tilt lines 29 and 30 and pockets 26 in the walls 25 for jacks to level each structure after erection.

A building that has been assembled from a number of multicellular, monolithic structures is shown in FIG. 4. In the construction of this building, a first row of three multicellular, monolithic structures 40, each having two rows of five cells, are first assembled in a horizontal plane, then tilted about a tilt line 41 to a vertical location. At the same time, a second row of three multicellular, monolithic structures 42 are assembled in a horizontal plane and then tilted about a tilt line 43 to a vertical location and mate with the three structures 40 in the first row. Spaces 44 and 45 remain between these mated structures in the rows and these in turn are filled with pre-cast concrete floor slabs 44A and 45A that are erected on each floor after the structures have been tilted to their vertical locations. In the next step, a third row of three multicellular, monolithic structures 46 are assembled in a horizontal plane and are tilted about tilt line 47 to their vertical locations so that they mate with the three structures 40 in the first row. At the same time, a fourth row of three similar structures 48 are assembled in a horizontal plane and tilted about a tilt line 49 to their vertical locations such that they mate against the three structures 42 in the second row. Pre-cast concrete panels are erected in the spaces 44 and 45 between the structures, and interior and exterior end walls are installed to complete the structure of the building.

The embodiment shown in FIG. 4 has tilt lines in one plane only. However, it will be apparent to those skilled in the art that the tilt lines could be in two planes at right angles to each other. This would provide vertical walls at right angles to each other. The multicellular, monolithic structures may be tilted to a vertical location so that all four sides of the structure eventually mate with adjacent structures. Alternatively only two opposing sides mate with adjacent structures as shown in FIG. 4 or in some cases no sides mate with adjacent structures. The spaces between the structures may be joined by floor slabs erected on each floor after the structures have been tilted to their vertical location and prefabricated end walls may be erected as required. The structures may be formed so that cantilevered floor sections mate between adjacent structures to avoid the necessity of having a vertical wall of one structure mating with an adjacent vertical wall of another structure.

An example of the fulcrum tilt position is shown in FIG. 5. A foundation wall 50 has a plate 51 mounted thereon and connected to reinforcing steel in the foundation wall 50. The plate has a V-notch 52 which forms the tilt line. A corner of the multicellular, monolithic structure 53 is shown in the vertical location, and has strengthened corner plates 54, preferably made of steel, positioned so that when the structure is tilted the corner plates 54 or tilt points are initially retained in the V-notch 52 and moves within the V-notch until the structure has moved through 90°. A jack 55, preferably a hydraulic jack, is located in a pocket 56 in the foundation wall 50 and is used for levelling the structure when it is raised to the vertical location. FIG. 6 shows a section through the foundation wall 50 with a guide angle 57 mounted on the steel plate 51 to act as a guide and retain the structure 53 in its correct location. The structure 53 has reinforcing steel 58 therein and is formed from concrete.

In the method of construction, the multicellular, monolithic structure first is assembled in the horizontal position in the manner disclosed herein. If the unit is made from concrete then it is essential to ensure that the concrete is cured before the tilting step commences. If it is formed from laminates such as wood or plastic then the laminate must be set before the tilting step commences to ensure that the structure has sufficient strength to avoid collapsing during the tilting step. Before commencing the next step, the location of the structure is checked to ensure it is in the correct position for the tilt step, the foundation walls are firm and the tilt plates 51, as shown in FIG. 5, are located with the V-notch 52 at the tilt line. The step of tilting is preferably carried out by two cranes although in small structures one crane is sufficient. Lifting hooks are connected at each side of the structure to a standard lifting bar or sling arrangement which is attached to the four top corners of the structure. When the lift commences the load comes on the two uppermost corners of the structure; then, as the cranes raise the structure and commence tilting it about the tilt line, the load spreads to the four corners of the structure until eventually when the centre of gravity of the structure passes over the tilt line, the load is transferred to the two uppermost corners again and the cranes prevent the structure from lowering too fast and damaging the foundation walls. Once the structure has been raised to its vertical location and is aligned within the angles 57, then the jacks 56 are used to ensure that the structure is level. After levelling, the jacks are removed and replaced by wedges or spacers on the foundation walls as required. After the structure has been tilted to its vertical location and levelled then exterior end walls may be added and internal walls as required. If the structure is to mate with one or more other structures, then it is necessary to ensure that the mating structures line up both vertically and horizontally. This may be done by the jacks. Curtain walls, glazed or pre-cast, may be fixed to the cell floor edges in the open ends of the structure. Recessed balconies, prefabricated internal walls or plain and simple masonry walls may be erected as required.

It will be appreciated that foundation walls may not be required and other types of foundation or slab may be used for a building. Such a system may be incorporated in the present invention in place of the foundation walls shown in FIGS. 5 and 6. In effect, a slab or raft foundation would reduce pressure at the line of contact during the tilting step, because the contact would not be restricted to the foundation walls.

Another embodiment of the present invention is shown in FIGS. 7 and 8. This embodiment is of particular interest in low-cost housing. Two halves of a house are assembled in a horizontal position. The first half 70 has two external walls 71, an internal wall 72 and a sloped roof 73 meeting at a central ridge 74. The second half 75 has two external walls 76, an internal wall 77 and a sloped roof 78 meeting at a central ridge 79.

The first half 70 has a ... 80 and the second half 75 has a tilt line 81 ... 82 match the external and interi... halves which both have floors 83 and 84. W... halves are tilted to their vertical locations th... 71, 72, 76 and 77 of the two halves 70 and 75 ... foundation walls 82 and a basement is formed ... floors 83 and 84 within the house. The two ... 70 and 75 are tilted about the fulcrum points 80 ... 81 to their vertical locations and a seal is provided ... between the two halves to prevent moisture entering ... loss of heat escaping from the house. Hydrauli... may be used as required to ensure that the two ... 70 and 75 meet after they have been tilted to their ... locations and are correctly aligned. End wall ... staircases and other interior walls and partitions are ... panels pre-cast and assembled after the two halves are erected. The multicellular, monolithic structure ... strength to the structure during the tilting step. The tilting of each half may be done by means of one crane with a lifting bar or sling arrangement attached to the two corners on each side of the central ridge 74, 79 of the roof 73, 78 or by two cranes each having a lifting bar arrangement attached to the four top corners of the structure.

Yet a further embodiment of the invention is shown in FIGS. 9 and 10 where a first structure 90 and a second structure 91 are tilted to a vertical location to mate and form a two-storey house. In this concrete foundation walls are required. A shallow pit 92 is prepared and filled with crushed stone 93. Two concrete strips 94 and 95 are prepared to support tilt lines 96 and 97. Each structure is assembled with a base floor 98 and 99 in place. It is after the tilting step the base floors 98 and 99 rest on the crushed stone 93. Concrete pads 100 are positioned at the sides of each structure to allow jacks to be used to level the two structures. The blocking or wedges may then be added and the jacks removed. A strong connection between the two halves is required to prevent their separating after the house has been assembled. This embodiment allows a house to be constructed without having to pour a concrete slab in the horizontal location. Only concrete strips 94 and 95 are required together with concrete jacking pads 100. In cold climates these strips and pads preferably have foundations below the frost line to prevent the completed building heaving in the spring thaw.

It will be apparent to those skilled in the art that a number of variations may be made within the framework of the present invention without departing from the scope thereof. It will be apparent to those skilled in the art that the engineering design of a structure suitable for tilting according to the present invention may be carried out without any inventive concepts being applied. Stresses due to the tilting step may be calculated dependent upon the weight of the structure and the design of the structure made to contain these stresses. The use of the crane is within the skill of a crane operator, the only tricky point being where the centre of gravity of the structure passes over the tilt line. Various have been referred to in this disclosure, but other lifting devices including jacks and winches may be used. The scope of this invention is not limited to buildings but may include other structures such as bridges, overpasses and the like.

The embodiments of the invention in which an exclusive property of privilege is claimed are defined as follows:

1. A method of constructing a building comprising the steps of:

forming at least one multicellular, monolithic structure on a horizontal plane, the formed structure having only vertical walls and having a forward lower edge in said horizontal plane;

providing a V-notch in the horizontal plane adjacent to said lower forward edge of said structure but out of contact therewith;

sliding and tilting said structure forward about said lower forward edge thereof until said edge enters and rests in said V-notch;

tilting said structure about said V-notch, and raising said structure to a vertical location, said lower forward edge leaving said V-notch during the raising of said structure; and

leveling said raised structure.

2. The method of constructing a building wherein a plurality of multicellular monolithic structures are assembled according to the method of claim 1 wherein spaces are provided between each structure and further including the step of filling each space with preformed floor slabs.

3. The method of constructing a building according to claim 1 wherein said forming step comprises forming the multicellular, monolithic structure in a horizontal plane by the slip-form method of pouring concrete which comprises providing a slip-form, pouring concrete into said slip-form, raising said slip-form, and repeating said pouring and raising steps a predetermined number of times.

4. The method of constructing a building according to claim 1 wherein the forming step comprises providing monolithic structure concrete forms made from rigid insulation, pouring concrete into said forms, leaving said forms in place after the walls are formed so that the rigid insulation remains with the structure to provide insulation for the building.

5. The method of constructing a building according to claim 1 and further including the additional steps of:

forming end walls from pre-cast panels; and

erecting the end walls after the structure has been tilted to the vertical position.

6. The method of constructing a building according to claim 1 wherein the step of providing a V-groove in the horizontal surface includes positioning a steel plate with a V-notch in the horizontal surface.

7. The method as claimed in claim 6 wherein said lower forward edge is defined by at least two corners, said method further comprising the step of positioning and attaching strengthened corner plates onto the corners of the formed structure, said corner plates being positioned and attached such that when said structure is tilted, said corner plates enter and rest in said V-notch.

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To all to whom these presents shall come:

Whereas a petition has been presented to the Commissioner of Patents praying for the grant of a patent for a new and useful invention, the title and description of which are contained in the specification of which a copy is hereunto attached and made an essential part hereof, and the requirements of the Patent Act having been complied with,

Now therefore the present patent grants to the applicant whose title thereto appears from the records of the Patent Office and is indicated in the said copy of the specification attached hereto, and to the legal representatives of said applicant for a period of seventeen years from the date of these presents the exclusive right, privilege and liberty of making, constructing, using and vending to others in Canada the invention, subject to adjudication in respect thereof before any court of competent jurisdiction.

Provided that the grant hereby made is subject to the conditions contained in the Act aforesaid.

In testimony whereof, these letters patent bear the signature of the Commissioner and the seal of the Patent Office hereunto affixed at Hull, Canada.

A tous ceux qui les présentes verront:

Considérant qu'une requête a été présentée au Commissaire des brevets, demandant la délivrance d'un brevet pour une invention nouvelle et utile, dont le titre et la description apparaissent dans le mémoire descriptif dont copie est annexée aux présentes et en fait partie essentielle, et que ladite requête satisfait aux exigences de la Loi sur les brevets,

A ces causes, le présent brevet confère au demandeur dont le titre de propriété audit brevet est établi d'après les dossiers du Bureau des brevets et est indiqué dans ladite copie du mémoire descriptif ci-annexé, et aux représentants légaux du dit demandeur, pour une période de dix-sept ans, à compter de la date des présentes, le droit, la faculté et le privilège exclusif de fabriquer, construire, exploiter et vendre à d'autres au Canada l'invention, sauf jugement en l'espèce par un tribunal de juridiction compétente.

La concession faite par les présentes étant soumise aux conditions contenues dans la loi précitée.

En foi de quoi ces lettres patentes portent la signature du Commissaire ainsi que le sceau du Bureau des brevets apposé à Hull, Canada.

JUIN 3 1980

Commissioner of Patents Commissaire des brevets

Attesting Officer Certificateur

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BUILDING SYSTEM AND PRECAST MODULE
FOR USE THEREIN

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(54) BUILDING SYSTEM AND PRECAST MODULE FOR USE THEREIN

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The present invention relates to a precast concrete building system where large precast modules are used combining horizontal slabs with wall or column support elements.

Various precast building systems are now being used in practice. Many precast building systems use separate precast elements in the form of columns, beams or joists and slabs. The disadvantage of known systems is that of requiring a plurality of segments, and of connections therebetween. The connections are usually placed at points where columns are joined with beams or slabs. This is a most undesirable place because of natural forces acting on buildings. In corners' junction between horizontal beams and vertical columns there is accumulation of vertical and horizontal forces together with shear and bending moments which makes connections very difficult and expensive. Single vertical elements like columns, have to be braced in both directions during the erections, so they will not overturn and bring a catastrophy. Plurality of different connections and their complexity make these systems in practice, limited in application and unecomonical.

Other systems use precast large size slabs and walls or panels. Panelized building systems can be seen as improvement while comparing with the post and beam systems, yet they are still difficult because of the plurality of different panels and of connections. They also require (especially wall panels) bracing during the construction against overturning and failure. Also known, are systems using precast concrete frames and slabs resting on them. Precast concrete frames are also disadvantageous because of the requirement for bracing in perpendicular planes. Other difficulties inherited by this system are the difficult connections of frames with floor panels. Known also are precast concrete systems where segments are prefabricated in the form

of complete boxes whereon boxes are made in the factory or in casting yard and then transported and stacked one on top of another. The box system is also uneconomical in practice, because of the requirement for very heavy cranes and the difficulties in transporting boxes which are very heavy and of large volume. The box system also does not allow the use of modern thin-wall ribbed concepts for the making of floor and wall slabs. The box system also requires very special and expensive forms for production.

It is a feature of the present invention to provide a precast building system which substantially overcomes all the above-mentioned disadvantages.

It is a further feature of the present invention to provide a construction module combining floor and wall or column into a single unit.

It is a further feature of the present invention to provide precast concrete modules which are self-supporting and where columns or walls and floor slabs are connected into single units that are easy to produce, to store, to transport and to erect.

It is a further feature of the present invention to utilize modules mainly for floors and walls, and in the form of a thin flat slab or waffle or ribbed slabs, where thin slabs being combined together with ribs provide stiffness and rigidity to precast modules as well as to the entire building after it is erected.

It is a further feature of the present invention to introduce precast concrete modules of large sizes which can extend from one to the other external wall of building, where apartments can be accommodated in between walls using conventional material for additional partitions.

It is a further feature of the present invention to

have wall elements or column elements projecting both ways from slabs upwards and downwards and to locate a connecting joint between modules in the middle heights between floors, where it is a most desirable place for accommodating forces acting on buildings (gravity forces, life load, horizontal forces, torsion, moments) such connections being simple because of loading basically only with vertical forces, and horizontal (shear) forces, without moments, thus making connections which are economical and simple. In some applications no structural connections are required except for the bearing of one element on top of another one. However, additional welded, bolted or post tensioned connections may be used, if desired, in cases of the presence of earthquake forces or uplift forces due to gas explosion or negative forces due to overturning wind loading etc.

According to a further feature, the present invention provides a system where only one type of precast element, or only a few types, are being used on construction sites whereon these elements may be used in any desirable way as one segment being stacked up on top of another one, or in a staggering manner, placed side-by-side to the other with some segments omitted or one placed on the other on a split-level basis. Another feature of this system, is that modules can be placed at a distance, thus providing gaps between them to accommodate partition walls or vertical conduits or stacks of plumbing and installation. Introduced here, prefabricated modules can be placed in a building at angles in a perpendicular direction, one to another, as it may be required for architectural purposes.

A still further feature is to provide a system where modules are connected in the middle between the upper and lower floor. This feature makes erection work very easy because of having connection at relatively low level, approximately four feet from the ground thus eliminating use of any working platform, ladders etc. It is possible, however, to shift the con-

connection upward or downward to the extreme case, when modules will resemble an open box or table. It is a further feature of this invention to use walls bent around the slab in an angle, in U-shape, or in rectangles up to a complete box shape or to have some walls completely omitted.

According to a broad aspect of the present invention, there is provided a prefabricated construction module for use in a building structure, said module comprising a horizontal rectangular slab section having opposed surfaces and at least two spaced apart transvere wall sections secured to said horizontal slab section and extending a predetermined distance above each said opposed surfaces to a height of substantially half a complete wall height where there is no bending moment, said wall sections constituting a load supporting projection when said module is juxtaposed with other modules in said building structure and said horizontal slab constituting a floor and ceiling surface by said opposed surfaces, respectively, for adjacent room sections, said wall sections having an end connecting edge for connection to a juxtaposed end connecting edge of a wall section of another module, and an extension support notch protruding beyond at least opposed ones of said wall sections extending in a direction parallel to the horizontal plane of said horizontal slab in an area of no bending moment to an end connecting edge situated to provide additional support outside the module for supporting flat panel members between adjacent modules for the construction of a building structure having strength properties comparable to a fully monolithic structure, said extension support notch being a projection of said horizontal slab.

The invention will now be described with reference to the preferred embodiment illustrated by the examples shown in the accompanying drawings in which:

FIGURE 1 is a perspective view of an example of a building being constructed with precast concrete modules of the present invention with different alternatives of the modules being shown and having full wall elements, wall elements with openings for windows, or with openings which make the walls in the form of columns, or having floor slabs extended vertically to create balcony railing:

FIGURE 2A is a perspective view of a module composed of a floor slab and wall:

FIGURE 2B is a perspective view of a module composed of floor slabs, wall slab, and columns;

FIGURE 2C is a perspective view of a module composed of a floor slab and columns and wall slab protruding only downward on one side, with no upward protrusion;

FIGURE 3A is a perspective view of a module having a floor slab combined with walls in the form of angles;

FIGURE 3B is a perspective view of a module having a U-shape wall slab;

FIGURE 3C is a perspective view of a module having a wall slab extending about the perimeter of the floor slab;

FIGURE 4A is a perspective view illustrating floor slabs extending into a balcony barrier;

FIGURE 4B is a perspective view illustrating both ways of an extension of the floor slab and bracket notch on wall slab to be used as a support for an intermediate floor panel;

FIGURE 4C is a perspective view illustrating the extension of a wall slab into a shelf which could be used as a stairway landing platform or other purpose;

FIGURE 5 is a perspective view of a two-storey module;

FIGURE 6A is a side elevation showing the construction of a building using different types of modules;

FIGURE 6B is a side elevation showing the construction of a building using modules and flat floor panels;

FIGURE 7A is a plan view showing the modules composed of flat slab, wall and columns, with openings for door and a gap in between the modules with additional cross-wall panel and open gap for vertical conduits;

FIGURE 7B is a plan view showing the use of modules where wall slabs are projecting in such a manner that flat panels can be supported in intermediate locations;

FIGURE 7C is a plan view showing a composition where

different modules and flat panels are being used for the construction of buildings including those oriented in perpendicular directions:

FIGURE 8A is an exploded perspective view of a connector showing a metal shoe embedded in concrete and a separate double cone insert to be placed in the opening guiding the upper segment during the erection time;

FIGURE 8B is a sectional view of the connection;

FIGURE 8C is a section view along section lines X-X of Figure 8B;

FIGURE 9 is a side view showing a stacking arrangement of modules for storage and transportation;

FIGURE 10A shows a plan view of a panel structure;

FIGURE 10B shows section in the direction perpendicular to the longitudinal axis of the panel of Figure 10A;

FIGURE 10C shows a section of a panel along longitudinal line;

FIGURE 11A shows a plan view of the mould for the production of a panel;

FIGURE 11B shows a sectional view of the mould along the longitudinal axis of the panel;

FIGURE 11C shows a sectional view of the structural concept of the mould in perpendicular direction to longitudinal axis of the panel;

FIGURE 11D shows examples of the use of a continuous mould for the production of panels of a different length, being multiples of basic modular component;

FIGURE 12A is a plan view of a module made using an economical structural system of thin-slabs, and ribs, where the ribs are distributed on a modular basis;

FIGURE 12B is a cross-sectional view along cross-sectional line X-X of Figures 12A, and

FIGURE 12C is a cross-sectional view along cross-sectional line Y-Y of FIGURE 12A.

Referring now to FIGURE 1, there is shown a partial building structure employing different construction modules A of this invention. The modules A each comprise essentially a span slab 1 having opposed transverse support projections 2 in the form of wall slabs 2' or column 2" whereupon, some modules have an "H" configuration when viewed from an end. Horizontal slab projections (4) can also be provided to constitute balconies. A projecting vertical slab 5 may extend outward from an end of the projection 4 to form a balcony barrier. This figure also shows how cut-outs of spaces between columns in vertical walls can be used for providing window or door openings, 6 and 7, respectively. This figure also shows a junction joint 8 formed between separate modules A and extending in a horizontal direction or in a zig-zag direction at 9 for providing additional shear resistance to the building. This figure also shows horizontal junction joints 10 between the longitudinal side edges of the floor slabs and vertical junction joints between the vertical side edges of adjacent transverse projections 2.

It can be seen from FIGURE 1, that separate modules A are being used here as self-supporting elements resting one on top of another. Projecting guide means 12 (in the form of pins or other suitable means) may be provided in order to guide the modules in place to simplify and speed the erection process of a structure. This figure shows a three-storey building of modules A which begins at ground level on a foundation 13 cast in place in the ground. However, this invention provides for the erection of buildings with a large number of floors, for example twenty or thirty, or more storeys being common and different types of foundations are provided depending on the building specification.

Referring now to FIGURES 2A to 2C there is shown

modules A having different transverse support projections. In particular, FIGURE 2A shows a standard module A with a span or floor slab 1 and wall projections 2' upward and downward. FIGURE 2B shows a module A with a floor slab 1 and wall slab 2' protruding upward on the left side, and columns 2" protruding upward on the right side. There are four columns 2" protruding downward two on each end of the slab 1. FIGURE 2C shows again, another example of module A where there is a floor slab 1 with a wall slab 2' protruding downward on the left, columns 2", of special curved shape, protruding upward on the left and a wall slab 2' with a zig-zag cut-out 14 projecting downward on the right. There is no support projection upward on the right side. All these segments in this case, have been illustrated with guide means 12 located in corners of transverse projections.

Referring now to FIGURES 3A to 3C, there is shown three examples, of different modules A with different wall slab configurations. In particular, FIGURE 3A shows a module A with transverse wall slabs 2' having a transverse corner extension 16 to form a slab 2" of "L"-shape. FIGURE 3B shows wall spans 2' protruding upwards defining "C" or "U" shape walls 17. FIGURE 3C shows a module A with walls 18 protruding upward and downward (18) about the entire periphery of the slab 1 to form a closed tube or open box.

Referring now to FIGURES 4A to 4C, there is shown modules A with different protrusions of the horizontal slab 1 and wall 2' or columns 2". FIGURE 4A shows a module A with a horizontal span slab 1 protruding both ways in the form of balconies 4 and a balcony railing 5 being provided with complete walls 2' or columns 2" having right angle cross-sections, such as shown at 20. FIGURE 4B illustrates a module A where in addition to balcony protrusion 4 and horizontal slab 1, a side protrusion 21 may be provided and the wall 2' may have an exten-

sion 22 on one side thereof. Further, an extension support notch 23 protrudes from the outer face of wall 2' and is provided to support intermediate flat panels 32 (see Fig. 6B) or other structural elements as it may be required in a particular structural design. FIGURE 4C illustrates again an example where the wall at the lower portion of the module has an extension flange 24 in the form of a horizontal slab which can be used as a landing platform for a stairway or as a beginning of a floor slab in staggered floor composition.

Referring now to FIGURE 5, there is shown a two-storey module B with two floor slabs 1a, projecting balconies 4a, a solid vertical wall 2'a projecting downward and upward and a full-storey, intermediate wall 25 on the left and with columns 4"a projecting downward and full-storey high columns 26 in between the floor slabs 1a with window openings 6a between columns and door openings 7a. This kind of two-storey module B can be produced as a homogeneous unit in the casting yard or prefabrication factory or produced out of single-storey modules A, as described earlier, and connected into two-storey module as it will be done in the erection of a building. In this particular embodiment two modules A are interconnected in the erection yard, and then lifted and placed in the building as a monolithic two-storey module B.

Referring now to FIGURES 6A and 6B, there is shown side elevation views of examples of structural systems for multi-storey buildings using different kinds of modules A and flat panels. In FIGURE 6A there is shown the use of different modules A with different floor extensions 4, 23 and 24, resting on spaced apart foundation walls 13 whereupon the different modules A are supported to form different floor levels. In one case a flat floor panel 27 is supported in between foundation walls 13 and different open spaces (29, 30, 31) are being created, in another case, flat panel 38a is used as a wall bearing. As

shown, one-storey regular spaces 31', as well as two-storey interior open spaces 29 and 30 or 1-1/2 storey open space 31 are formed. This figure shows how modular large-size prefabricated building modules A can be used to create various different spaces as it may be required for functional and architectural purposes.

FIGURE 6B illustrates a building with a regular horizontal one-level floor arrangement but which is achieved by using a combined structural system composed of flat span panels 32 staggered with different configuration of modules A such as at 34, 35 and 36 whereupon these modules A are resting directly on foundation footings 33 thus creating half-storey high crawl spaces 37. This figure also illustrates how different modules A are arranged in a staggering manner so there are no places where all horizontal junctions in the building would be located in the same vertical plane. This arrangement makes buildings stronger, and allows the making of horizontal junctions between the modules and flat panels in a simple manner without special interlocking and horizontal force-resisting connecting elements. Both the above illustrations, FIGURE 6A and FIGURE 6B are given as examples of the use of the modules of the present invention and many other configurations are possible to suit particular designs.

Referring now to FIGURES 7A-C, there are shown in plan, different building plans where different modules A are used to create different buildings. Varieties of modules A with regular horizontal slabs 1 with or without projections 4 are used together with intermediate horizontal panels 40 resting on wall extension 22a on notch extensions 23 as described and shown in FIGURE 4B. Vertical panels 38 may also be supported by wall extension 22 to form side walls. The modules A are arranged in such a way that open spaces 39 may be created between them for locating

sion 22 on one side thereof. Further, an extension support notch 23 protrudes from the outer face of wall 2' and is provided to support intermediate flat panels 32 (see Fig. 6B) or other structural elements as it may be required in a particular structural design. FIGURE 4C illustrates again an example where the wall at the lower portion of the module has an extension flange 24 in the form of a horizontal slab which can be used as a landing platform for a stairway or as a beginning of a floor slab in staggered floor composition.

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Referring now to FIGURES 6A and 6B, there is shown side elevation views of examples of structural systems for multi-storey buildings using different kinds of modules A and flat panels. In FIGURE 6A there is shown the use of different modules A with different floor extensions 4, 23 and 24, resting on spaced apart foundation walls 13 whereupon the different modules A are supported to form different floor levels. In one case a flat floor panel 27 is supported in between foundation walls 13 and different open spaces (29, 30, 31) are being created, in another case, flat panel 38a is used as a wall bearing. As

shown, one-storey regular spaces 31', as well as two-storey interior open spaces 29 and 30 or 1-1/2 storey open space 31 are formed. This figure shows how modular large-size prefabricated building modules A can be used to create various different spaces as it may be required for functional and architectural purposes.

FIGURE 6B illustrates a building with a regular horizontal one-level floor arrangement but which is achieved by using a combined structural system composed of flat span panels 32 staggered with different configuration of modules A such as at 34, 35 and 36 whereupon these modules A are resting directly on foundation footings 33 thus creating half-storey high crawl spaces 37. This figure also illustrates how different modules A are arranged in a staggering manner so there are no places where all horizontal junctions in the building would be located in the same vertical plane. This arrangement makes buildings stronger, and allows the making of horizontal junctions between the modules and flat panels in a simple manner without special interlocking and horizontal force-resisting connecting elements. Both the above illustrations, FIGURE 6A and FIGURE 6B are given as examples of the use of the modules of the present invention and many other configurations are possible to suit particular designs.

Referring now to FIGURES 7A-C, there are shown in plan, different building plans where different modules A are used to create different buildings. Varieties of modules A with regular horizontal slabs 1 with or without projections 4 are used together with intermediate horizontal panels 40 resting on wall extension 22a on notch extensions 23 as described and shown in FIGURE 4B. Vertical panels 38 may also be supported by wall extension 22 to form side walls. The modules A are arranged in such a way that open spaces 39 may be created between them for locating

vertical panels or vertical installation conduits, or unused open spaces 42. In these examples, there are different vertical elements being used in the form of vertical walls 2' or columns 2" or special "L" shaped columns 20. Larger extensions 41 of floor slab 1 are also shown in FIGURE 7C.

Referring now to FIGURES 8A-C, there is shown the detail construction of connector 60 to be used between the modules A. In particular, FIGURE 8A shows a connector arrangement between a wall slab 2' and column 2" resting thereon. FIGURE 8B shows a vertical and horizontal section through this connection. This particular connection is given as an example only and other type connectors may be suitable for interconnection. The main elements of this connector 60 consists of a prefabricated metal shoe or inserts 43 in the form of a square cup with a round conical inward cavity 44. When one module is being erected, on alignment pin in the form of a double cylinder metal cone 45 is being placed into the cavity 44 of a module which just been erected. This cone 45 when placed in position serves as the guide means 12, already described. A U-shape metallic spacer plate 46 is placed about the cone 45 to form a gap between interconnected modules. Different thicknesses of plates 46 may be used as it will be required in order to achieve perfect horizontal alignment of modules. Another important function of this plate 46 is to create a gap in junctions 8 or 9 between erected modules A which has to be filled with cement mortar, dry pack, epoxy or other filling of compression force resisting material. Cone 45 and plate 46 may be replaced with alternative set comprising bolt and nut.

In cases where a building may be subjected to possible uplift forces due to extreme load, horizontal wind forces, or earthquake forces, it may be required to provide securement means for resistance against tensile forces acting upward, between upper and lower modules. In such cases, an additional steel plate 47 or a number of plates can be placed on vertical faces of

both shoes 43 and connected to them by means such as welding. After the welding operation is completed, the exposed metal shoe and the connecting plates 47 can be covered with covering mortar 48. For that purpose, shoes have smaller dimensions than the column or walls. In every case, metal shoes 43 have to be integrally connected with the columns or walls. For this purpose, metal studs 49 having hooks or anchors 50 are welded to metallic shoes. The diameter of these studs or anchors and the length has to be defined by static calculation on the basis of anticipated pull-up or uplift forces. As has already been mentioned, any other connection between upper and lower modules A can be used and has been foreseen as part of this invention. However, it is recommended to use guides as shown in Fig. 8, for the purpose of simplifying the alignment and erection process. The configuration of the joints could be changed to provide additional horizontal resistance against possible horizontal or shearing forces if required. For example, the joints could be made with projections or zig-zag configurations, as already shown in FIGURE 1.

Referring now to FIGURE 9, there is shown three modules A placed one on top of another in a staggered manner, and transported on a vehicle platform 70. The same staggering arrangement can be used for storing of the modules A in a prefabrication yard or factory. The invention does introduce large-size prefabricated modules which can be stored at a minimum volume or the minimum space consumption.

Referring now to FIGURES 10A-C there is shown a flat panel which can be used for walls or floors such as designated by numerals 1, 2', 38, 38a and 40. In particular, FIGURE 10A shows the schematic plan of such a panel. FIGURE 10B shows alternatives of a longitudinal section of the panel and FIGURE 10C shows an

alternative of the cross-section of the panel. One panel is made as a multiple of the modular component panels cast jointly in a multiple modular mould of length being of multiple of a basic module as it may be required for the design. The panel is composed of a thin wall slab 51 which may be of very little thickness such as 1" or 1-1/2" or more, as it may be required because of local code regulations. The required rigidity of the panels themselves, and of the whole building afterwards is provided by means of the perimeter ribs 52, 53 or 54 along a longitudinal direction and ribs 55, 56, 57 and 58 along the short direction and intermediate ribs (59). Different kinds of longitudinal and end ribs are shown here as they may be required for particular locations of panel in the building. For example, the rib 53 and similarly, rib 58 correspond to panels being used in the floor where the configuration of the ribs, when panels are placed side-by-side, creates a space which after being filled in with concrete makes the interlocking arrangement able to carry the shear force in the structure. Ribs 54 and 56 respectively are designed for panels being supported or notches of adjoining panels as described before. Rib type 52 or 57, respectively, apply to panels which may be used in walls as panel 38a shown in Fig. 6A where ribs are finished under perpendicular angle creating flat surfaces used for bearing of one element on top of another. Also, intermediate ribs can be configurated in a different manner, for example, as shown in the longitudinal section as rib 59 or reduced in size rib 60. The panels can be produced as solid elements without openings or with different openings 61 as may be required. In this particular case, opening 61 provides for accommodation of window or door. In this sense, panels can be seen as stressed skin made of thin slab and rigid ribs where the ribs are arranged in a grid like manner. The depth of it is defining rigidity and strength of the floor or wall including the resis-

tance against buckling. The depth and the size of the ribs can be chosen accordingly to design requirements. Thus, the designed panels provide structural elements of minimum consumption of structural materials. Also, they are economical to use in building construction. Panels can be reinforced in any practical and code-acceptable manner. The most practical reinforcement arrangement is done by means of welded wire fabric 64 in the slab, longitudinal reinforcing bar in cross-ribs 62 and main reinforcing bars 63 in long ribs. Diameter of these bars can be chosen in accordance with the working conditions of the particular panel. A stronger reinforcement 63 will be required for panels used for floors. Lesser reinforcement will be required for panels used in walls.

Referring now to FIGURES 11A-D, there is shown the mould for producing the panels previously described with reference to FIGURES 10A and 10B. In particular, FIGURE 11A shows schematically fragment of the plan of the mould. FIGURE 11B shows a fragment of the longitudinal section. FIGURE 11C shows a schematically perpendicular section of the mould. FIGURE 11D shows two examples of how panels of different multiples in this case, of three-module multiples, two-module multiples, four-module multiples, and so on could be cast in continuous mould. Structure of the mould can be made out of a number of boxes 65 placed and fixed to the base 66. All boxes are of the same size corresponding to modular rib arrangement of the panel. The edge elements 67 are placed along both sides of the boxes in a distance providing space accommodation for longitudinal ribs (like 52, 53 or 54). In the same manner, edge elements 68 are placed at the beginning and at the end of so described mould. Now, in case of required opening to be provided in the panel, a frame 69 can be placed on the top of the particular box 65 where concrete will not be placed during the casting operation, thus

creating space open for window to come. For obtaining of panels of different lengths, in so designed continuous mould, dividers 70 are being placed in the mould in places, as desired. Thus, a universal casting arrangement is being designed where, in a continuous long mould, different panels of different module multiples for example, double multiples, triple multiples, quadruple multiples, and so on, can be achieved, in continuous and thus economic casting operation. As it has been mentioned before, the same mould can be used for the production of panels for walls and floors, except the particular panels will differ with the amount and kind of major reinforcement being placed in the longitudinal ribs. Other reinforcements, like mesh in the slab, secondary reinforcement in cross-ribs, will be provided for structural purpose, thus of the same kind and of minimum consumption of the amount of steel. Different configuration of edges 53, 54, 56, 57, 58, etc. can be achieved by placing in the moulds of different blocking inserts.

Referring now again to FIGURE 12A there is shown a plan view and sections of a large-size module combining a flat panel and a wall element and column, in form of an economic system combining thin-wall slab 51 with cross-ribs 59, longitudinal ribs 52 or 53, in the same manner as it was done in the place of flat panels. The purpose of this figure is to illustrate the concept of production where continuous moulds can be used both for production of flat panels as well as large-size space modules described earlier, whereupon ribs are distributed in a modular manner, and whereupon modules of different multiples can be produced with walls or columns projecting outward and downward from floor planes, in locations as it may be desired. This figure also illustrates how different size modules can be produced in the same specially designed continuous mould.

FIGURE 15 demonstrates one example of how modules subject to this invention can be made. It is possible to make these modules in any other way that it may be desired for architectural or other functional reasons. For example, it is possible to make a flat wall for floor and walls in the form of a single thickness - slab or with any rib arrangements, where the number and pattern of ribs can vary, as required.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:-

1. A prefabricated construction module for use in a building structure, said module comprising a horizontal rectangular slab section having opposed surfaces and at least two spaced apart transverse wall sections secured to said horizontal slab section and extending a predetermined distance above each said opposed surfaces to a height of substantially half a complete wall height where there is no bending moment, said wall sections constituting a load supporting projection when said module is juxtaposed with other modules in said building structure and said horizontal slab constituting a floor and ceiling surface by said opposed surfaces, respectively, for adjacent room sections, said wall sections having an end connecting edge for connection to a juxtaposed end connecting edge of a wall section of another module, and an extension support notch protruding beyond at least opposed ones of said wall sections extending in a direction parallel to the horizontal plane of said horizontal slab in an area of no bending moment to an end connecting edge situated to provide additional support outside the module for supporting flat panel members between adjacent modules for the construction of a building structure having strength properties comparable to a fully monolithic structure, said extension support notch being a projection of said horizontal slab.

2. A module as claimed in claim 1 wherein said module is made from precast concrete.

3. A module as claimed in claim 1 wherein said extension support notch is a straight horizontal edge.

4. A module as claimed in claim 1 wherein said wall sections are constituted by columns each having an end connecting edge, said columns having at least one section thereof aligned in a common plane.

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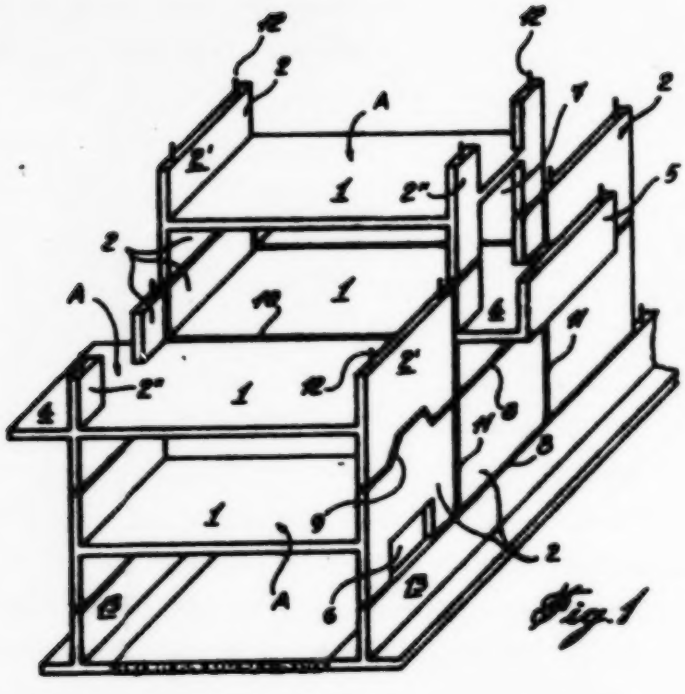

Fig. 1

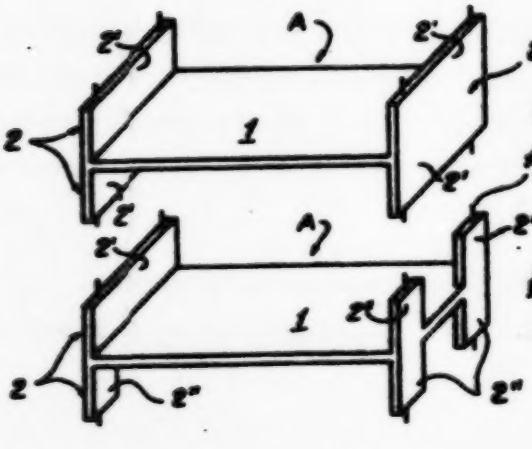

Fig. 2A

Fig. 2B

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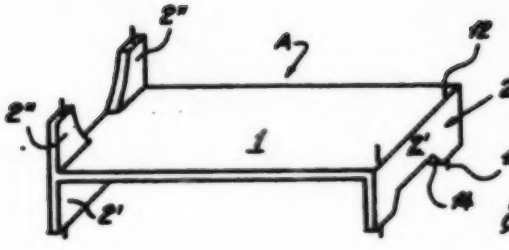

Fig. 2C

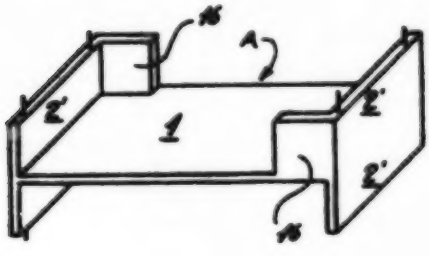

Fig. 3A

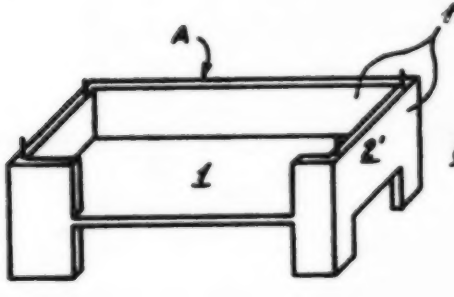

Fig. 3B

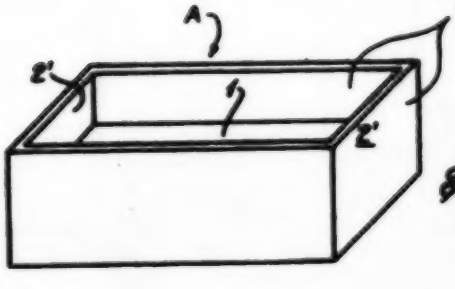

Fig. 3C

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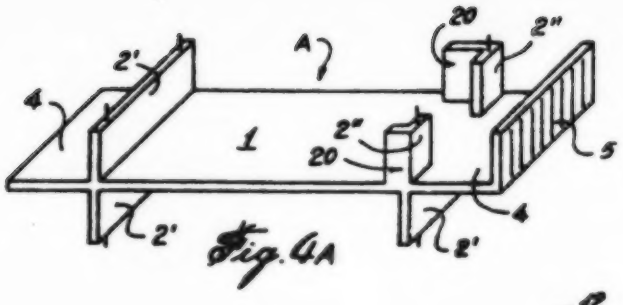

Fig. 4A

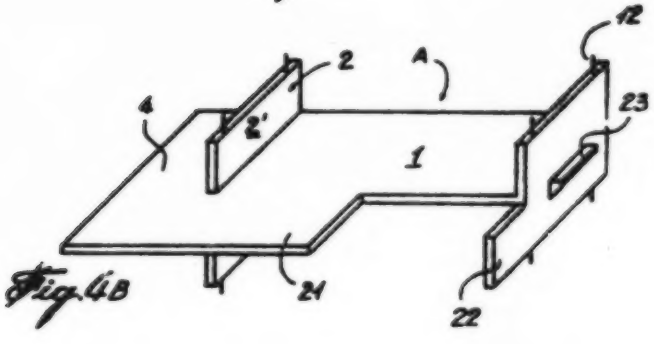

Fig. 4B

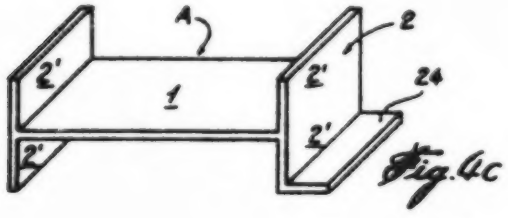

Fig. 4C

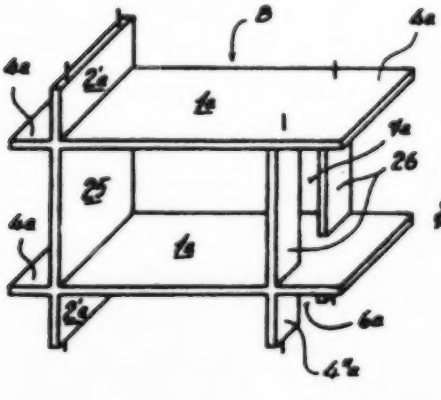

Fig. 5

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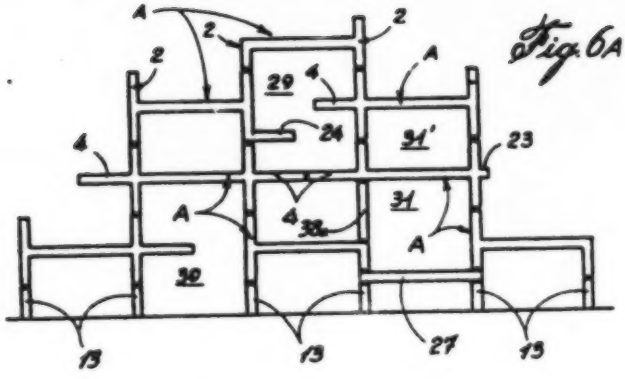

Fig. 6A

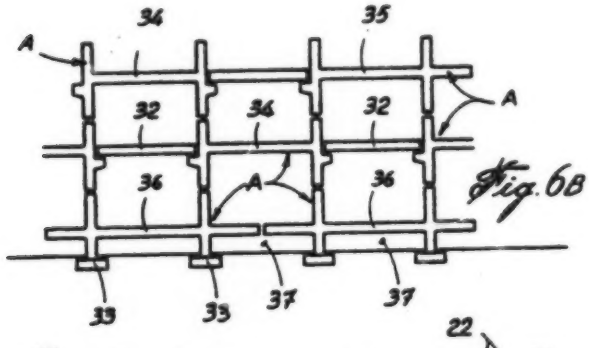

Fig. 6B

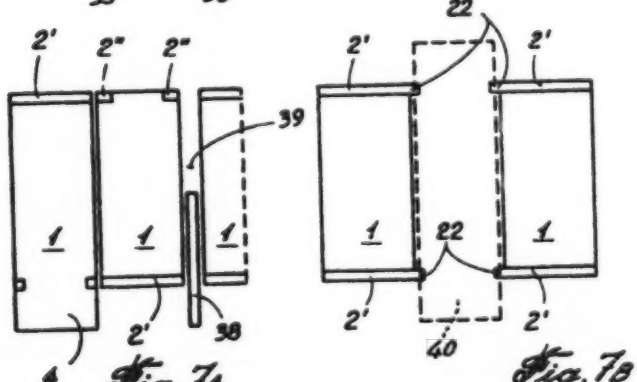

Fig. 7A

Fig. 7B

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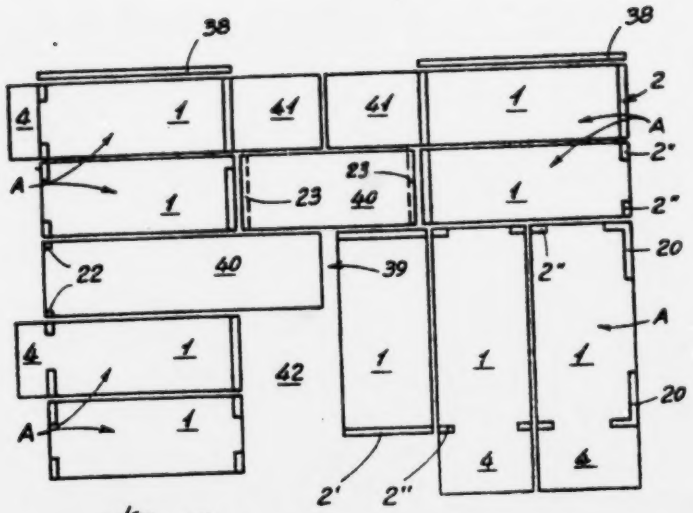

Fig. 7c

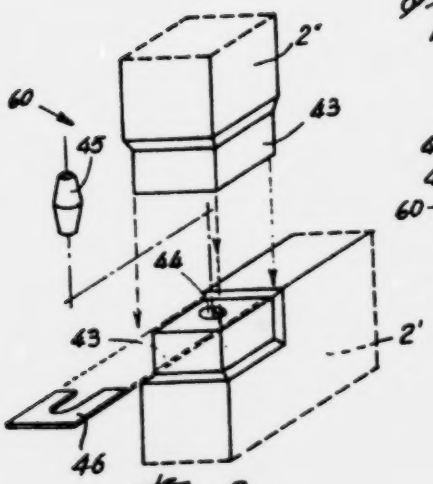

Fig. 8A

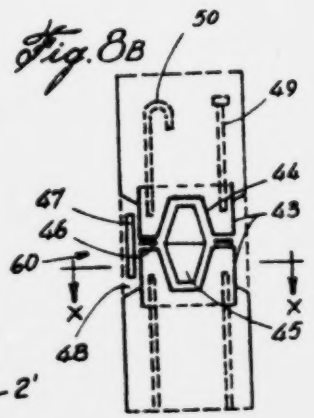

Fig. 8B

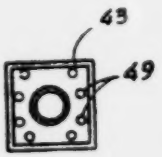

Fig. 8C

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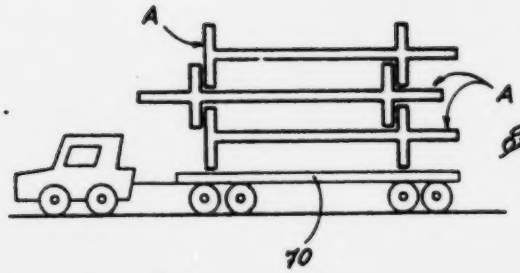

Fig. 9

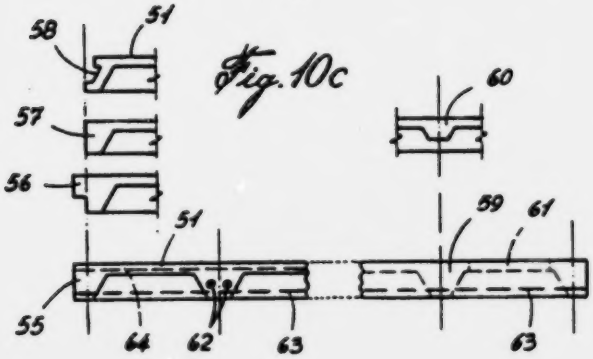

Fig. 10C

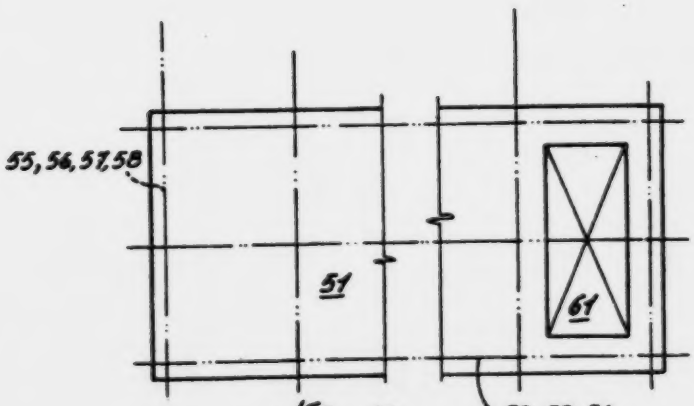

Fig. 10A

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Fig. 12C

Fig. 12B

Fig. 12A

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United States Patent [19]

Zielinski et al.

[11] **4,248,020**

[45] **Feb. 3, 1981**

[54] **PRECAST CONCRETE**

[75] Inventors: **Zenon A. Zielinski; Czeslawa Zielinski, both of Montreal, Canada**

[73] Assignee: **Canadian Patents & Development Ltd., Ottawa, Canada**

[21] Appl. No.: **46,470**

[22] Filed: **Jun. 7, 1979**

[30] **Foreign Application Priority Data**

Jul. 31, 1978 [CA] Canada 308414

[51] Int. Cl.³ E04F 11/14

[52] U.S. Cl. 52/185; 52/79.1; 52/189

[58] Field of Search 52/79.1; 184, 185, 189

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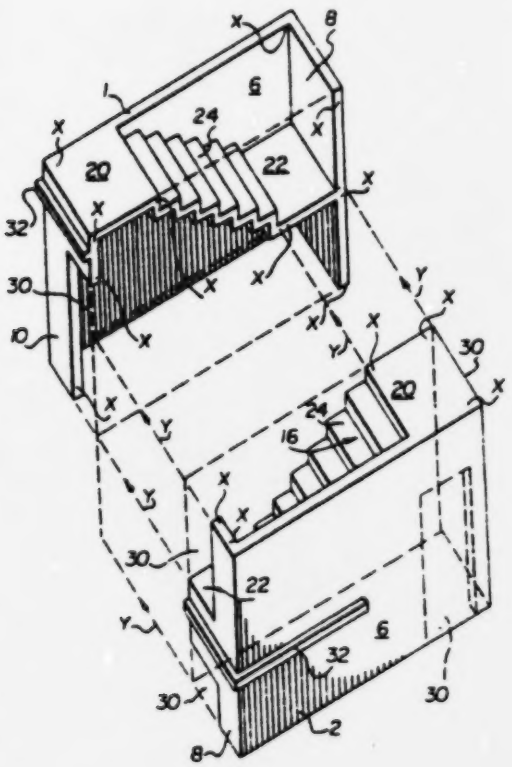
Primary Examiner—J. Karl Bell

Attorney, Agent, or Firm—Francis W. Lemon

[57] **ABSTRACT**

A precast concrete stairway module comprising a concrete wall assembly which is C-shaped in plan view, providing a side wall and two end walls, a concrete stair flight extending from an edge of one side wall to a mid-height position of the other side wall. The stair flight assembly is moulded integrally with the wall assembly and comprises a landing at each end and a flight of stairs therebetween. An access opening is provided in the wall assembly.

4 Claims, 7 Drawing Figures



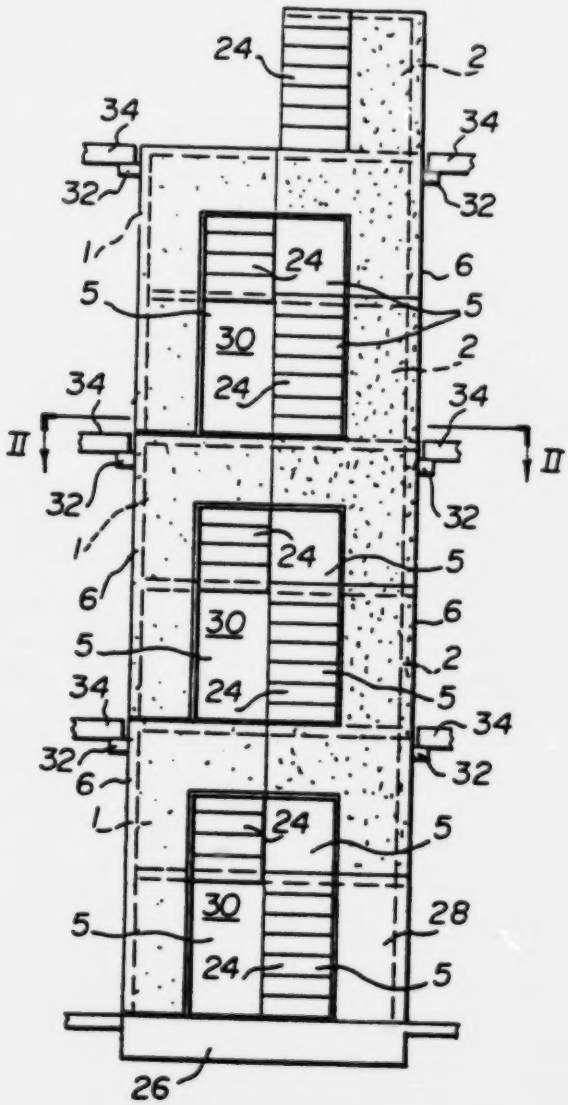

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FIG. 1

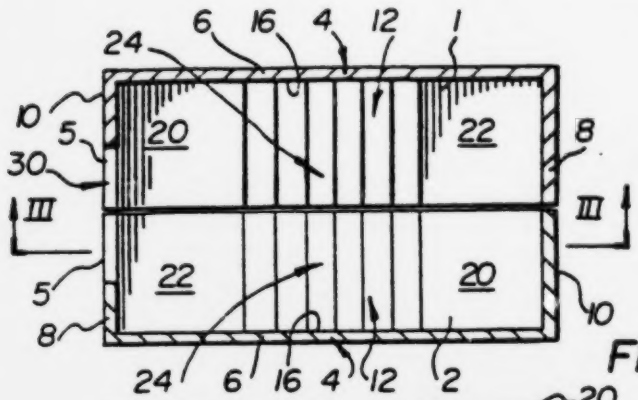
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FIG. 2

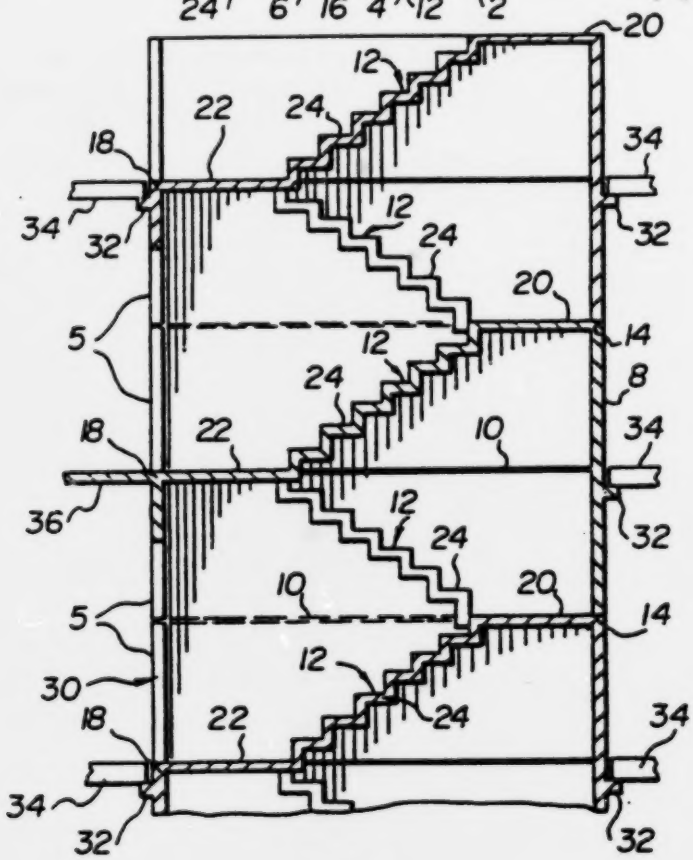
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FIG. 3

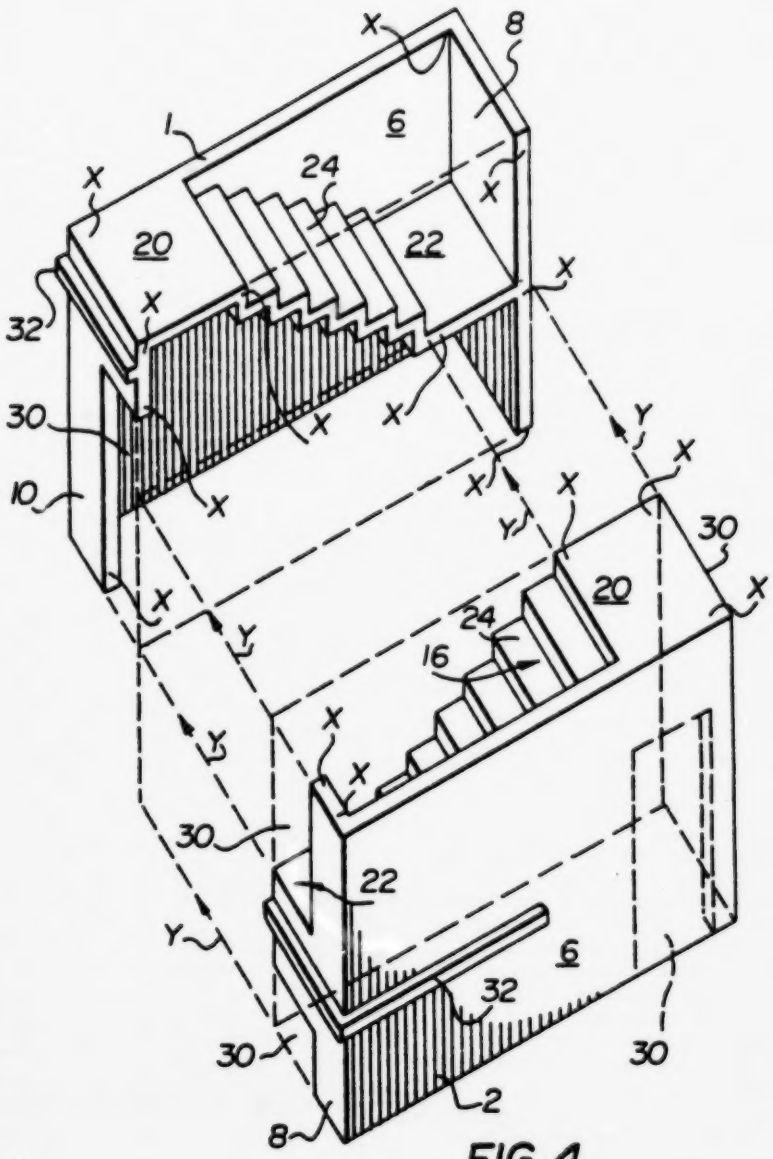


FIG. 4

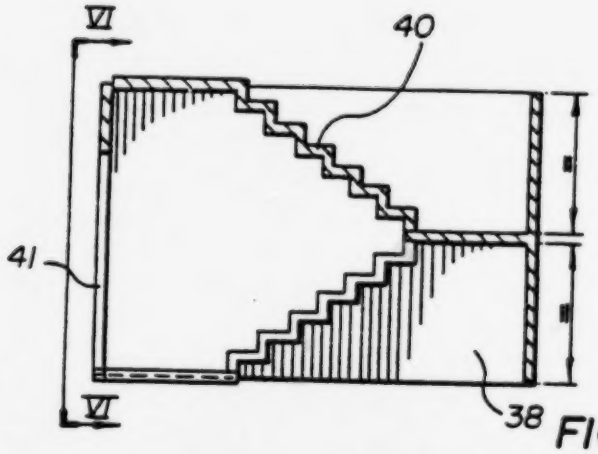


FIG.5

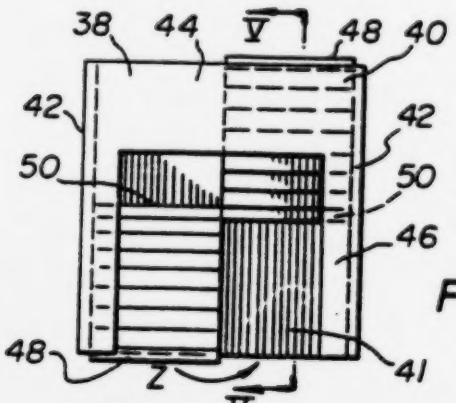


FIG.6

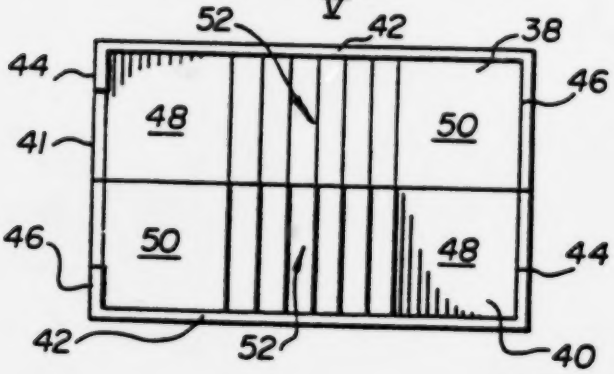


FIG.7

PRECAST CONCRETE STAIRWAY MODULE

This invention relates to a precast concrete stairway module. Existing building codes require that every high rise building such as, for example, an apartment or public building is provided with at least two stairways which can be used as fire exits. These stairways are required to be fire resistant with a required fire resistance rating of one or two hours as the case may be.

Concrete is known for its good fire resistance and so many of the stairways are constructed from concrete or reinforced concrete. The stairway itself is a rather complicated structural element in buildings. Construction of stairways in concrete technology is quite difficult and expensive. Most concrete stairways are built using concrete blocks by casting reinforced concrete on site as the basic structural material. The use of the above mentioned structural materials makes the construction of stairways slow and time consuming. In many cases, the stairways cannot be built at the same time as the building is being erected. In such cases, temporary stairs (or ladders) have to be erected in order to allow movement of construction labour, which are replaced later by permanent stairways. This practice adds to the cost of the building construction.

Attempts have been made to introduce prefabricated stairways in order to eliminate the above mentioned disadvantages. Several prefabricated stairway systems are being used. For example, separate prefabricated steps and landing platforms are used which are made from reinforced concrete or steel. The plurality of prefabricated separate elements used in such systems makes the construction of stairways still expensive and difficult because of the plurality of the connections and high accuracy required in mating parts.

There still exists a need to provide a system which substantially overcomes all the above mentioned disadvantages.

There is also a need to provide a construction module which combines many elements of a stairway including walls, steps and landing platforms into a single unit.

It would also be desirable to provide precast concrete modules which are self supporting where walls, landing platforms and steps are connected into a single unit which is easy to produce, to transport and erect.

According to the present invention, there is provided a precast concrete stairway module, comprising

(a) a concrete wall assembly having an access opening and which is C-shaped in plan view to provide a side wall and two end wall portions, and

(b) a concrete stair flight assembly within the wall assembly and extending from a marginal edge portion of a first one of the end wall portions, along an inner side of the side wall, to a mid-height portion of a second one of the end wall portions, the stair flight assembly being moulded integrally with the wall assembly and comprising a landing at each end with a flight of stairs extending therebetween.

The present invention provides precast stairway modules which are placed in the position and interconnected by, for example, welding, bolts or post tensioning cables placed at selected points of an interface plate, to create a rigid tube-like structural system with extremely high strength for normal, vertical load and with additional strength to support horizontal forces due to wind or earthquake. The latter feature facilitates the use of the stairways to provide lateral stability to the building during the erection and useful life of the building.

The precast stairway modules of the present invention may be erected before the construction of the building and are immediately useful after the erection thereof.

The precast stairway modules of the present invention can be located inside a building, as is the case with most conventional buildings, or they can provide free standing stairway-wells, located outside of the building such as, for example, with buildings of the gallery type. The precast stairway modules of the present invention can be used for the construction of additional stairways to existing buildings.

It is a feature of the present invention that a fire resistant stairway is provided by the precast stairway modules which can be used as a fire exit, because the required fire resistance can be provided to any required fire rating by simply providing walls of corresponding thickness.

The precast stairway modules can be equipped with projecting brackets to support adjoining floors which can be made in any material such as, for example, timber, concrete prefabricated slabs. Modules can also be equipped with projecting cantilevering slabs which are a part of adjoining floors.

Openings in walls of the precast stairway modules can be provided for doors and windows in places as may be required in a particular architectural design.

In the present invention, only one basic type of module is made in a single mold or identical molds which makes prefabrication simple and inexpensive. Separate modules may differ from each other by a different size and the locations of openings and in some cases by a different arrangement of the projecting floor slabs or brackets. These differences are obtainable in the same precasting mold or similar ones by providing the or each mold with supplementary inserts and forming units.

In general, the present invention provides a system which uses a single mold produced module allowing a construction of high rise stairways of any height in number of floors able to support gravity loads from stairway and adjoining floors if required and to provide lateral resistance to the building resulting from the fact that the stairways, when erected and when the elements are properly interconnected, behaves like a rigid monolithic tube-like structure. The important feature of this system is the simplicity in erection, full stability at every erection stage and the elimination of the necessity for using any temporary bracing or supporting for lateral stability. The modules can be erected by simply placing them side by side, one on top of another one, without any additional connections therebetween.

In the accompanying drawings which illustrate, by way of example, embodiments of the present invention,

FIG. 1 is an end view of a stairway assembled from a plurality of precast concrete stairway modules,

FIG. 2 is a sectional plan view along II—II, FIG. 1,

FIG. 3 is a sectional side view along III—III, FIG. 2, of an upwardly extending portion of the stairway,

FIG. 4 is an exploded corner view of two of the stairway modules shown in FIGS. 1 to 3,

FIG. 5 is a sectional side view along V—V, FIG. 6, of two more or less identical precast concrete stairway modules which are different to those shown in FIGS. 1 to 4,

FIG. 6 is an end view along VI—VI, FIG. 5, and

FIG. 7 is a plan view of FIG. 5.

In FIGS. 1 to 3, there is shown a stairway comprising a plurality of precast concrete stairway modules, generally designated 1 and 2. Each prefabricated stairway module 1 and 2 comprising:

(a) a concrete wall assembly 4 having an access opening 5 which is C-shaped in plan view to provide a side wall 6 and two end wall portions 8 and 10, and

(b) a concrete stair flight assembly 12 within the wall assembly 4 and extending from a marginal edge portion 14 of a first one, designated 8, of the end wall portions, along an inner side 16 of the side wall 6, to a mid-height portion 18 of a second one, designated 10, of the end wall portions, the stair flight assembly 12 being moulded integrally with the wall assembly 4 and comprising a landing 20 or 22 at each and a flight of stairs 24 extending therebetween.

In this embodiment, the bottom left hand module 1 is placed on a foundation slab 26 which is designed in accordance with the loads which the stairway is expected to carry and the soil conditions. A special bottom right hand module 28, which is equivalent to the landings 20 and 22, stairs 24 and the portions of the side wall 6 and end walls 8 and 10 contained between the levels of the landings 20 and 22, is placed on the foundation slab 26 against the bottom left hand module 1. The special bottom right hand module 28 is positioned on the foundation slab 26 turned through 180°, about a vertical axis, relative to the bottom left hand module 1 to form therewith a bottom portion of a stairway. The bottom left hand module 1 and the special bottom right hand module 28 are secured and sealed together and to the foundation slab 26 in a conventional manner. The assembly of the stairway is then proceeded with by placing a right hand module 2 on the special bottom right hand module 28 and securing and sealing the right hand module 2 to the special bottom right hand module 28 and to the bottom left hand module 1. A second left hand module 1 is then placed on the bottom left hand module 1 and is secured and sealed to the bottom left hand module 1 and to the right hand module 2. The assembly of the stairway is then continued in this manner by placing each additional right hand module 1 on the right hand module side followed by each additional left hand module 2 on the left hand module side until the stairway is completed.

Doorways, such as doorways 30 comprising the access openings 5 and/or windows (not shown) are cast into the walls, 6, 8 and/or 10 by providing removable cores in the moulds for the modules 1, 2 and 29. It should be noted that the removable cores required for access openings 5 providing portions of each doorway 30 in the left hand modules 1 are different from those required for the portions of each doorway 30 in the right hand modules 2 and the special bottom right hand module 28.

In this embodiment, each stair flight assembly 12 spans downwardly from the marginal edge portion 14 of the first one of the end wall portions 5.

As previously stated the landings 20 and 22 and/or the stairs 24 are moulded integrally with the side walls 6 and the end walls 8 and 10.

External support brackets 32 on the wall assembly 4 may be cast integrally with the modules 1 and 2 for supporting adjacent floors 34. In different embodiments, adjoining floors, such as floors 36, are moulded integrally with the modules 1 and 2.

In FIG. 4, similar parts to those shown in FIGS. 1 to 3 are designated by the same reference numerals and the previous description is relied upon to describe them.

It can be seen from FIG. 4 that the modules 1 and 2 are basically geometrically similar except for the portions of doorways 30, and the positions of support brackets 32, which can be provided in a mould by removable inserts so that a plurality of similar moulds can be used for the production of all of the modules 1 and 2. The dashed lines and the arrows Y show how both of the modules 1 and 2 are positioned against one another to form portions of the stairway.

For the purposes of the required sound insulation and fire resistance it will be necessary to make joints between the modules 1 and 2 which are solid and air tight. This can be achieved by filling in all of the joints with grout, cement, mortar or an epoxy resin. The structural integrity of a stairway, which works as a monolithic tube, can be achieved by providing special structural connections. Different means of connection are possible including bolting, post tensioning or welding of steel plates against embedded steel inserts. Suitable structural points for placement of bolted or welded connections are designated X in FIG. 4. The number, the capacity and location of structural connections has to be determined for each individual project by calculation. However, in cases where the staircase is not used as structural elements providing horizontal resistance and structural stability to the building, no special structural connections are required, except for filling in of joints. The most convenient way of production of modules is by arranging the moulds in such a way that the modules 1 and 2 are cast horizontally with the side walls 6 at the top of the mould and the steps 16 and the landings 20 and 22 cast vertically.

In FIGS. 5 to 7, there are shown two stairway modules 38 and 40 which are identical, except for the position of the doorway 41, which can be used to construct a stairway without a special bottom module such as module 28 in FIG. 1.

The modules 38 and 40 each comprise a side wall 42, end wall portions 44 and 46, landings 48 and 50 and stairs 52.

In this embodiment, the module 38 is first placed in position and then the module 40 oriented in an upside down position in the direction of arrow Z (FIG. 6), from the orientation of the module 38, is placed in position next to the module 38. A number of modules 39 and 40 can be stacked in this manner to provide a stairway.

It will be appreciated that in this embodiment the landings 48 and 50 are designed to support a load on either side, i.e., whichever side is uppermost when the module is in use. Further, the landings 48 preferably protrude one half of their thickness beyond the side wall 42 and end walls 44 and 46 to avoid a step between two adjacent landings 48 and 50 and to provide a locating means between the lowest modules and the foundation slab and between adjacent modules in the vertical direction.

We claim:

1. A precast concrete stairway module, comprising:

(a) a concrete wall assembly having an access opening and which is C-shaped in plan view to provide a side wall and two end wall portions, and

(b) a concrete stair flight assembly within the wall assembly and extending from a marginal edge portion of a first one of the end wall portions, along an inner side of the side wall, to a mid-height portion

of a second one of the end wall portions, the stair flight assembly being moulded integrally with the wall assembly and comprising a landing at each end with a flight of stairs extending therebetween.

2. A module according to claim 1, wherein the stair flight assembly spans downwardly from the marginal edge portion of the first one of the end wall portions.

3. A module according to claim 1, which includes external brackets on the wall assembly for supporting adjacent floors.

4. A module according to claim 1, which includes an adjoining floor integral with wall assembly.

* * * * *

"APPLICABLE STANDARDS FOR DESIGN AND CONSTRUCTION OF SITE PRECAST BUILDING STRUCTURES"

APPLICABLE STANDARDS FOR DESIGN AND CONSTRUCTION OF SITE PRECAST BUILDING STRUCTURES

Alberta Building Standards, 1981

National Building Code of Canada, 1980

CSA Standards:

CAN 3 - A23.1 - M77
Concrete Materials and Methods of Concrete Construction

CAN 3 - A23.3 - M77
Code for the Design of Concrete Structures for Buildings

CAN 3 - A23.4 - M81
Precast Concrete -- Materials and Construction

American Concrete Institute Standard 301-72

Specifications for Structural Concrete for Buildings

the province

OCTOBER 6, 1982

Ottawa hikes forest ante

By PATRICK DURRANT

The federal government is prepared to more than double its spending on forest renewal if the provincial governments and industry will do the same, federal Environment Minister John Roberts announced in Vancouver Tuesday.

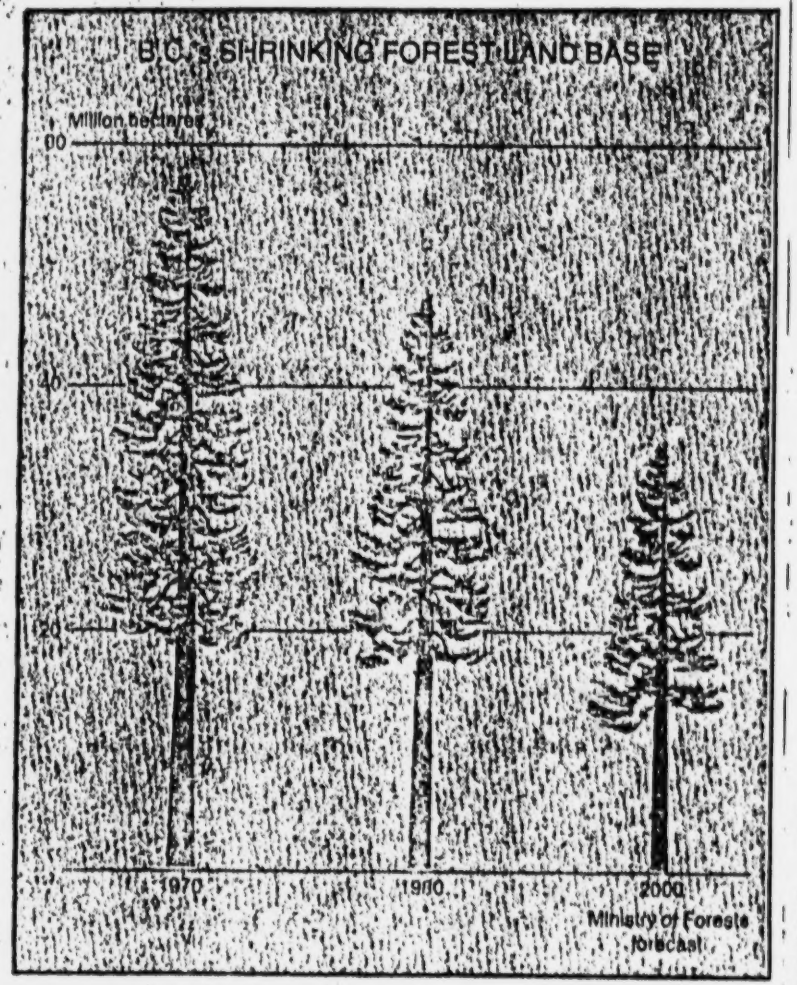
Roberts, who is responsible for the Canadian Forestry Service, said Ottawa's contribution would be part of a proposed combined government-industry annual spending level of $650 million for forest renewal, more than double the $300 million now laid out.

"We are going to increase our effort from $50 million to a minimum of $130 million annually over five years," Roberts said, adding later that British Columbia could expect to get 30 to 40 per cent of Ottawa's contribution, or around $40 to $50 million annually.

The rest of the money needed for forest renewal in B.C. would have to come from the provincial government and the industry; B.C. Forests Minister Tom Waterland could not be reached for comment.

Robert made his announcement at the 85th annual convention of the National Hardwood Lumber Association. The bulk of the association's membership is American and the Canadian hardwood firms represented are almost all from Eastern Canada.

The federal government is entering into forest-renewal agreements with each of the provinces, Roberts said. Federal funds will be applied to intensive timber stand improvement, while the provinces and industry will be expected to carry the major responsibility for basic forestry.



Foresters say more money must be provided to manage and regenerate B.C.'s forest resource. Since 1970, the theoretical forest land base has been reduced from 58 million hectares to 47 million, and a further 25 per cent decline by the year 2000 is forecast.

"We have to shift the way we manage our forest resources, from mining them to farming them," he said. "Government needs to have constructive discussions with the private sector if we are to succeed in our objective."

Earlier, Roberts' top official in the Canadian Forestry Service, assistant deputy minister Les Reed, said formal scrutiny of forest management might be necessary if the present level of activity does not improve.

"If by this time next year there isn't a better effort by the provinces, then I would be ready to recommend that an audit committee be formed with industry representatives to look at regeneration and rehabilitation of specific areas," Reed said, speaking to foresters at a symposium on forest-management financing.

"We need to have a land-use ethic in Canada," he said. "We haven't had the forest bequeathed to us — we have borrowed it from our children."

In similar vein, Jack Munro, western regional president of the International Woodworkers of America, told the symposium the land question is the most critical in B.C. for the forest industry.

"It should be harder in B.C. to alienate forest land than it is to alienate farm land," he said. "We have to have a forest land commission that is at least as tough as the farm land commission."

The government has so far designated 118 multi-use provincial forests for timber harvesting, grazing, recreation and wildlife.

"FOREST RENEWAL & PROJECTED LUMBER SHORTFALLS"

from

The Province

Vancouver, B.C.

Oct. 6, 1982

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